GOODMAN
MINING HANDBOOK

FOR

Coal and Metal Mine Operators, Managers, Etc.

Third Edition
1919

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PRESENTATION

PUBLICATION of this third edition of the Goodman Mining Handbook has been long deferred because of war conditions — the shortage of paper, the scarcity of leather, etc.—which made it wholly improper to divert from more important uses the materials which go to make up a volume of this character.

The book is now offered as a pocket or desk reference aid to the mining man who wants short cuts to desired results in ordinary calculations, and handy data to relieve his mind of the burden of attempting to hold in memory the important formulas and practices of his daily work.

The following pages contain some new matter, necessary revision of statistical data, and extension of the Goodman product summary. The Goodman Manufacturing plant has received several successive additions until now it appears as shown by the new view on opposite page.

As heretofore, much of the material in the present book has been arranged from data of the Goodman Manufacturing Co., and its accuracy is based on long experience. Many of the tables and much of the general information have been calculated and arranged expressly for this handbook; other matter has been derived from standard sources of recognized authority and reliability.

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Resistance of

Copper and Aluminum Wire

at 75° Fahrenheit

Conductivity: Copper 98%; Aluminum 62%.

Wire No., B.&S. Gauge	Area, Circular Mils	Copper: Volts Lost per Ampere Per 1000 Feet	Copper: Volts Lost per Ampere Per Mile	Copper: Feet per Ohm	Aluminum: Volts Lost per Ampere Per 1000 Feet	Aluminum: Volts Lost per Ampere Per Mile	Aluminum: Feet per Ohm
0000	211600	0.049	0.259	20393	0.078	0.410	12888.9
000	167805	.062	.327	16172	.098	.517	10236.9
00	133079	.078	.412	12825	.123	.652	8118.5
0	105592	.098	.519	10176	.155	.822	6441.7
1	83695	.124	.655	8066	.196	1.036	5105.8
2	66373	.156	.825	6396.7	.247	1.306	4049.1
3	52634	.197	1.04	5072.5	.311	1.646	2546.5
4	41743	.249	1.31	4022.9	.393	2.075	3210.9
5	33102	.314	1.66	3190.2	.496	2.620	2019.4
6	26251	.395	2.09	2529.9	.625	3.305	1601.4
7	20817	.499	2.63	2006.2	.789	4.173	1269.9
8	16510	.629	3.32	1591.1	.994	5.255	1007.2
9	13094	.792	4.18	1262.0	1.253	6.627	798.8
10	10382	1.00	5.28	1000.5	1.580	8.360	633.3
11	8234	1.26	6.65	793.6	1.990	10.53	502.32
12	6530	1.59	8.39	629.3	2.513	13.29	398.35
13	5178	2.00	10.58	499.1	3.167	16.75	315.90
14	4107	2.53	13.34	395.8	3.992	21.10	250.54
15	3257	3.19	16.82	313.9	5.035	26.66	198.68
16	2583	4.02	21.21	248.9	6.345	33.55	157.55
17	2048	5.07	26.75	197.4	8.013	42.30	124.95
18	1624	6.39	33.73	156.5	10.11	53.40	99.09
19	1288	8.06	42.53	124.1	12.73	67.25	78.58
20	1021	10.16	53.64	98.44	16.07	85.06	62.31
21	810.1	12.81	67.63	78.07	20.25	107.1	49.42
22	642.5	16.15	85.27	61.92	25.53	134.9	39.20
23	509.5	20.37	107.5	49.10	32.20	170.3	31.08
24	404.0	25.68	135.6	38.94	40.65	214.8	24.65
25	320.4	32.38	171.0	30.88	51.23	271.0	19.55
26	254.1	40.84	215.6	24.49	64.65	341.8	15.50

Properties of

Stranded Copper and Aluminum Cable

at 75° Fahrenheit

Conductivity: Copper 98%; Aluminum 62%

Wire No., B.&S. Gauge	Area, Circular Mils	Copper: Weight of Bare Cable, Pounds		Copper: Volts Lost per Ampere per 1000 Feet	Aluminum: Weight of Bare Cable, Pounds		Aluminum: Volts Lost per Ampere per 1000 Feet
		Per 1000 Feet	Per Mile		Per 1000 Feet	Per Mile	
	1000000	3050	16104	0.0105	920	4858	0.0166
	950000	2898	15299	.0111	874	4617	.0175
	900000	2745	14494	.0117	828	4374	.0185
	850000	2593	13688	.0124	782	4131	.0196
	800000	2440	12883	.0131	736	3888	.0207
	750000	2288	12078	.0140	690	3645	.0221
	700000	2135	11273	.0150	644	3402	.0237
	650000	1983	10468	.0162	598	3159	.0256
	600000	1830	9662	.0175	552	2916	.0276
	550000	1678	8857	.0191	506	2673	.0302
	500000	1525	8052	.0210	460	2430	.0332
	450000	1373	7247	.0234	414	2187	.0370
	400000	1220	6442	.0263	368	1944	.0416
	350000	1068	5636	.0300	322	1701	.0474
	300000	915	4831	.0350	276	1458	.0553
	250000	762	4026	.0420	230	1215	.0664
0000	211600	645	3405	.0497	194.7	1028	.0785
000	167805	513	2709	.0625	154.4	816	.0987
00	133079	406	2144	.0789	122.4	647	.1247
0	105592	322	1700	.0995	97.1	513	.1573
1	83695	255	1346	.1258	77.0	407	.1988
2	66373	203	1072	.1579	61.0	323	.2495
3	52634	160	845	.2004	48.5	256	.3168
4	41743	127	671	.2525	38.5	203	.3990
5	33102	103	544	.3112	30.2	161	.4920
6	26251	81	428	.3960	24.1	128	.6260

Weight of
Bare Copper Wire

Wire No., B. & S. Gauge	Diameter, Inches	Area, Circular Mils	Weight of Bare Wire, Pounds	
			Per 1000 Feet	Per Mile
0000	0.460	211600	640.7	3383
000	.410	167805	508.1	2683
00	.365	133079	403.0	2128
0	.325	105592	319.7	1688
1	.289	83695	253.4	1338
2	.258	66373	201.0	1061
3	.229	52634	159.4	841.5
4	.204	41743	126.4	667.4
5	.182	33102	100.2	529.2
6	.162	26251	79.5	419.7
7	.144	20817	63.0	332.8
8	.129	16510	50.0	264.0
9	.114	13094	39.7	209.4
10	.102	10382	31.4	166.0
11	.091	8234	24.9	131.7
12	.081	6530	19.8	104.4
13	.072	5178	15.7	82.8
14	.064	4107	12.4	65.7
15	.057	3257	9.86	52.07
16	.051	2583	7.82	41.29
17	.045	2048	6.20	32.75
18	.040	1624	4.92	25.97
19	.036	1288	3.90	20.59
20	.032	1021	3.09	16.33
21	.029	810.1	2.45	12.95
22	.025	642.5	1.95	10.27
23	.023	509.5	1.54	8.15
24	.020	404.0	1.22	6.46
25	*.018*	320.4	.97	5.12
26	*.016*	254.1	.77	4.06

Breaking Strength of

Copper and Aluminum Wire and Cable

Ultimate strength of Annealed Copper taken at 34,000 pounds per square inch.
Ultimate strength of Hard Drawn Copper taken at 60,000 pounds per square inch, except: 50,000 pounds for Nos. 0000, 000 and 00; 55,000 pounds for No. 0; 57,000 pounds for No. 1.
Ultimate strength of Aluminum taken at 26,000 pounds per square inch.
Table gives actual breaking strains, to which a suitable safety factor must be applied to secure proper working strengths.

Wire No., B. & S. Gauge	Area, Circular Mils	Breaking Strain, Pounds			
		Copper, Solid		Aluminum	
		Annealed	Hard Drawn	Solid	Stranded
	1000000	....	......	20420	32280
	900000	....	......	18380	29050
	800000	....	......	16340	25820
	700000	....	......	14300	22590
	600000	....	......	12250	19370
	500000	....	......	10210	16140
	400000	....	......	8170	12910
	300000	....	......	6130	9680
	250000	....	......	5110	8070
0000	211600	5650	8310	4320	6830
000	167805	4475	6580	3430	5420
00	133079	3550	5226	2720	4290
0	105592	2800	4558	2150	3410
1	83695	2225	3746	1710	2700
2	66373	1775	3127	1355	2143
3	52634	1400	2480	1075	1700
4	41743	1115	1967	852	1350
5	33102	885	1519	657	1070
6	26251	700	1237	536	850
7	20817	550	980	426	....
8	16510	440	778	337	....
9	13094	350	617	267	....
10	10382	275	489	212	....
11	8234	220	388	167	....
12	*6530*	175	307	133	....
13	*5178*	135	244	105	....
14	*4107*	110	193	84	....

Comparison of Wire Gauges

Diameters in Inches for Various Gauge Systems

Gauge No.	Brown & Sharpe, American Std.	Whitworth's, English Standard	English Imperial Legal Standard	Birmingham or Stubbs'	Birmingham for Iron Sheets	Lancashire	Warrington or Rylands
0000	.460	....	.400	.454	......	......	.406
000	.409	....	.372	.425	......	......	.375
00	.364	....	.348	.380	......	......	.343
0	.324	....	.324	.340	......	......	.326
1	.289	.001	.300	.300	.312	.227	.300
2	.257	.002	.276	.284	.281	.219	.274
3	.229	.003	.252	.259	.250	.209	.250
4	.204	.004	.232	.238	.234	.204	.229
5	.181	.005	.212	.220	.218	.201	.209
6	.162	.006	.192	.203	.203	.198	.191
7	.144	.007	.176	.180	.187	.195	.174
8	.128	.008	.160	.165	.171	.192	.159
9	.114	.009	.144	.148	.156	.191	.146
10	.101	.010	.128	.134	.140	.190	.133
11	.090	.011	.116	.120	.125	.189	.117
12	.080	.012	.104	.109	.112	.185	.100
13	.071	.013	.092	.095	.100	.180	.090
14	.064	.014	.080	.083	.087	.177	.079
15	.057	.015	.072	.072	.075	.175	.069
16	.050	.016	.064	.065	.062	.174	.062
17	.045	.017	.056	.058	.056	.169	.053
18	.040	.018	.048	.049	.050	.167	.047
19	.035	.019	.040	.042	.043	.164	.041
20	.031	.020	.036	.035	.037	.160	.036
21	.028	....	.032	.032	.034	.157	.031
22	.025	.022	.028	.028	.031	.152	.028
23	.022	....	.024	.025	.028	.150	....
24	.020	.024	.022	.022	.025	.148	....
25	.017	....	.020	.020	.023	.146	....
26	.015	.026	.018	.018	.021	.143	....
27	.014	....	.016	.016	.020	.141	....

Diameter and Weight of

Standard Weatherproof Insulated Copper Wire and Cable

Double Braid

Wire No., B. & S. Gauge	Area, Circular Mils	Solid		Stranded	
		Diameter, Inches	Weight, Pounds per 1000 Feet	Diameter, Inches	Weight, Pounds per 1000 Feet
	1000000	....	....	1.37	3456
	900000	....	....	1.31	3127
	800000	....	....	1.24	2799
	700000	....	....	1.18	2471
	600000	....	....	1.11	2093
	500000	....	....	1.03	1765
	400000	....	....	.94	1436
	300000	....	....	.85	1083
0000	211600	0.61	723	.71	745
000	167805	.56	587	.65	604
00	133079	.52	467	.60	482
0	105592	.47	377	.56	388
1	83695	.41	294	.47	303
2	66373	.37	239	.42	246
3	52634	.35	185	.38	190
4	41743	.32	151	.35	155
5	33102	.30	122	.32	126
6	26251	.28	100	.31	103

Diameter and Weight of

Standard Weatherproof Insulated Copper Wire and Cable

Triple Braid

Wire No., B. & S. Gauge	Area, Circular Mils	Solid		Stranded	
		Diameter, Inches	Weight, Pounds per 1000 Feet	Diameter, Inches	Weight, Pounds per 1000 Feet
	1000000	....	....	1.45	3674
	900000	....	....	1.39	3332
	800000	....	....	1.33	2992
	700000	....	....	1.27	2650
	600000	....	....	1.19	2235
	500000	....	....	1.11	1894
	400000	....	....	1.02	1553
	300000	....	....	.93	1174
0000	211600	0.66	767	.79	800
000	167805	.60	629	.73	653
00	133079	.55	502	.66	522
0	105592	.51	407	.61	424
1	83695	.45	316	.52	328
2	66373	.40	260	.44	270
3	52634	.37	208	.41	219
4	41743	.35	164	.38	170
5	33102	.32	130	.35	146
6	26251	.30	112	.33	115

Diameter and Weight of

Rubber Insulated Copper Wire and Cable

National Electric Code Standard. 0 to 600 Volts

Double Braid

Wire No., B. & S. Gauge	Area, Circular Mils	Solid		Stranded	
		Diameter, Inches	Weight, Pounds per 1000 Feet	Diameter, Inches	Weight, Pounds per 1000 Feet
	1000000	....	....	1.46	3553
	900000	....	....	1.40	3223
	800000	....	....	1.33	2891
	700000	....	....	1.27	2557
	600000	....	....	1.19	2220
	500000	....	....	1.09	1842
	400000	....	....	1.00	1514
	300000	....	....	.90	1173
0000	211600	0.70	793	.77	833
000	167805	.65	646	.71	675
00	133079	.61	528	.66	556
0	105592	.57	439	.61	457
1	83695	.53	363	.57	377
2	66373	.45	276	.50	293
3	52634	.42	228	.45	238
4	41743	.39	190	.42	198
5	33102	.36	154	.40	166
6	26251	.34	130	.36	136
7	20817	.30	105	.32	108
8	16510	.27	82.1	.29	85.5
9	13094	.26	68.4	.27	70.0
10	10382	.25	58.1	.26	60.6
11	8234	.24	50.0	.25	52.3
12	6530	.23	43.1	.24	44.9
13	5178	.22	38.5	.23	39.6
14	4107	.21	33.0	.22	34.3

Diameter and Weight of

Rubber Insulated Copper Wire and Cable

National Electric Code Standard. 0 to 600 Volts

Triple Braid

Wire No., B. & S. Gauge	Area, Circular Mils	Solid		Stranded	
		Diameter, Inches	Weight, Pounds per 1000 Feet	Diameter, Inches	Weight, Pounds per 1000 Feet
	1000000	....	....	1.54	3637
	900000	....	....	1.48	3304
	800000	....	....	1.42	2968
	700000	....	....	1.35	2631
	600000	....	....	1.28	2290
	500000	....	....	1.17	1906
	400000	....	....	1.09	1573
	300000	....	....	.99	1226
0000	211600	0.78	835	.85	879
000	167805	.73	685	.79	719
00	133079	.69	564	.74	595
0	105592	.65	474	.70	494
1	83695	.61	395	.66	412
2	66373	.51	297	.59	324
3	52634	.48	247	.52	260
4	41743	.46	208	.49	218
5	33102	.41	167	.46	184
6	26251	.39	142	.41	149

Allowable Current-Carrying Capacity of Copper Wires

For Inside Wiring of Buildings

National Board of Fire Underwriters' Rules

Wire No., B. & S. Gauge	Area, Circular Mils	Resistance, Ohms per 1000 Feet	Amperes	
			Rubber Covered	Other Insulation
	2000000	.00524	1050	1670
	1800000	.00582	970	1550
	1600000	.00655	890	1430
	1400000	.0075	810	1290
	1200000	.00875	730	1150
	1000000	.0105	650	1000
	800000	.013	550	840
	600000	.018	450	680
	400000	.026	330	500
	200000	.052	200	300
0000	211600	.049	210	312
000	167800	.063	177	262
00	133100	.079	150	220
0	105500	.100	127	185
1	83690	.126	107	156
2	66370	.158	90	131
3	52630	.200	76	110
4	41740	.252	65	92
5	33100	.316	54	77
6	26250	.400	46	65
8	16510	.685	33	46
10	10380	1.05	24	32
12	6530	1.6	17	23
14	4107	2.56	12	16

Fusing Currents for Wires

Of Various Materials

Amperes of current required to fuse wires of lengths sufficient to render negligible the cooling action of the terminals.

Wire No., B. & S. Gauge	Wire Diam., Inches	Material					
		Copper	German Silver	Iron	Lead	Tin	Lead 2, Tin 1
10	.10189	333	169	101	44.8	53.3	43.0
11	.09074	284	146	86.0	38.2	45.4	36.6
12	.08080	235	120	71.2	31.6	37.6	30.3
13	.07196	200	102	63.0	26.9	32.0	25.8
14	.06408	166	85.2	50.2	22.3	26.6	21.4
15	.05707	139	71.2	42.1	18.7	22.2	17.9
16	.05082	117	60.0	35.5	15.7	18.8	15.1
17	.04526	99.0	50.4	32.6	13.3	15.8	12.8
18	.04030	82.8	42.5	25.1	11.1	13.2	10.7
19	.03589	66.7	34.2	20.2	8.96	10.6	8.60
20	.03196	58.3	29.9	17.7	7.84	9.31	7.50
21	.02846	49.3	25.3	14.9	6.63	7.89	6.35
22	.02535	41.2	21.1	12.5	5.53	6.60	5.32
23	.02257	34.5	17.7	10.9	4.44	5.52	4.45
24	.02010	28.9	14.8	8.76	3.89	4.62	3.72
25	.01790	24.6	12.6	7.46	3.31	3.93	3.17
26	.01594	20.6	10.6	6.22	2.77	3.30	2.66
27	.01419	17.7	9.10	5.36	2.38	2.83	2.28
28	.01264	14.7	7.50	4.45	1.98	2.35	1.90
29	.01126	12.5	6.41	3.79	1.68	2.00	1.61
30	.01002	10.3	5.26	3.11	1.38	1.64	1.32
35	.00561	4.37	2.24	1.33	.586	.701	.55
40	*.00314*	1.86	.95	.56	.251	.298	.24

Volts Lost with Various Copper Wire Combinations

Sizes of Wires	Area, Circular Mils.	Weight of Combination, Pounds per 1000 feet.	Volts Lost per Ampere per 1000 feet.
One No. 0000 and One No. 000	379405	1149	0.027
" " " " " 00	344679	1044	.030
" " " " " 0	317192	960	.033
" " " " " 1	295295	894	.035
One No. 0000 and Two No. 000	547210	1657	.019
" " " " " 00	477758	1447	.022
" " " " " 0	422784	1280	.025
" " " " " 1	378990	1148	.027
One No. 000 and One No. 00	300884	911	.035
" " " " " 0	273397	828	.038
" " " " " 1	251500	762	.041
One No. 000 and Two No. 00	433963	1314	.024
" " " " " 0	378989	1147	.027
" " " " " 1	335195	1015	.031
One No. 00 and One No. 0	238671	723	.043
" " " " " 1	216774	656	.048
One No. 00 and Two No. 0	344263	1042	.030
" " " " " " 1	300469	910	.035
One No. 0 and One No. 1	189287	573	.055
One No. 0 and Two No. 1	272982	827	.038

Rail Bonds

PURPOSE—The purpose of a rail bond is to provide an electrical connection between rail ends, and thus cut down the power loss at rail joints in case the rail is used as a return for the electric current.

SELECTION—There are two major classes of bonds, namely the protected and the exposed.

If the roadbed is well laid, as on a main haul, it is advisable to use the protected bond, placed under the joint plate. If, however, the road bed is not solid and if there is likely to be more or less shifting and movement of the rail ends, the exposed bond should be used, as it can be inspected more readily than a bond placed under the fish plate.

A third class of bond, the semi-protected type, is really a combination of the two major classes. In this type, the body or central part of the bond is placed under the fish plate, while the terminals are located beyond the ends of the plate. This arrangement possesses some of the advantages of the protected bond and also permits ready inspection of the terminals.

The use of a bond whose resistance is as low as that of the rail would necessitate an initial expense which would not be offset by a corresponding gain in power. A loss, therefore, is suffered at each rail joint. The allowable resistance of the bond varies from .0001 to .0004 ohms, depending on the general economics of the construction.

Although no fixed rule can be prescribed for determining the proper size of bond to use, the following table gives the sizes generally found satisfactory:

Rails 16 pounds and lighter	0	bond
" 20 to 30 pounds	00	"
" 35 to 50 pounds	0000	"
" 60 pounds and heavier	2—0000	"

If protected or semi-protected bonds are to be used, their size must be determined with due consideration of the availabl space under the joint plate so as to prevent binding by the pla

Rail Bonds—Continued

Exposed bonds should be 10 inches longer than the fish plate. Cross bonds should be 12 inches longer than the width of the track gauge. Use of bonds too short usually results in breakage due to crystallization.

INSTALLATION—A bond is no better than the joint it makes with the rail. In order to assure a good electrical contact, the hole in the rail should be the exact size of the bond terminal; and the bond should be applied immediately after the hole is drilled. If this is impracticable, all rust, dirt or moisture should be cleaned out of the hole before applying the bond.

Both rails should be bonded. Cross bonds should be applied every 100 or 150 feet.

Particular attention should be given to bonding around switches and frogs.

If the terminal is welded to the rail, care should be taken to avoid any oxidizing flame which takes the life out of the material.

The pressure applied to compressed terminals should be sufficient to cause the metal actually to flow and thus become forced into good contact with the rail.

MAINTENANCE—The rail bonding should be inspected at regular intervals, loose terminals tightened and broken bonds replaced.

Feeling for hot rail joints or shaking the bond to see if it is loose is a guess work method of testing bonds. A bond may be tight and still make a poor contact with the rail, due to a film of oil or some foreign matter being lodged between the terminal and the rail.

The proper method of testing bonds is to use a bond testing meter. This bond tester gives the resistance of the rail joint and bond in terms of length of rail. If it is established that a properly installed bond should be equivalent to 4 feet of rail, all bonds which test out to have a resistance greater than this amount should be given attention. With the use of a bond tester, a large number of bonds can be tested accurately in a short time.

Volts Drop in Bonded Track

Volts Lost per Ampere per 1000 Feet of Single Track
(Ohms per 1000 Feet)

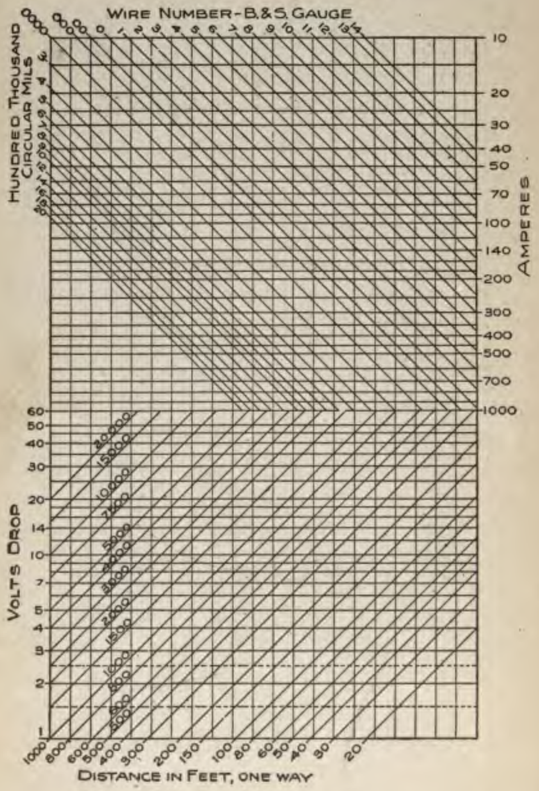
Both Rails Bonded

Resistance ratio of rail to copper, 11½ to 1.

Rail Weight, Pounds per Yard	Fish Plate Length, Inches	Length of Exposed Bond, Inches	Bond Size, Wire Gauge	Rail Lengths, Feet	Volts Loss per Ampere per 1000 Feet
8	16⅛	26	0	20	0.0587
12	16⅛	26	0	20	.0409
16	16⅛	26	0	20	.0319
20	16⅛	26	2/0	20	.0256
25	16⅛	26	2/0	20	.0214
30	16⅛	26	2/0	20	.0184
35	16⅛	26	4/0	20	.0149
40	20	30	4/0	30	.0119
50	24	36	4/0	30	.0102
60	24	36	2–4/0	30	.0085
70	34	44	2–4/0	30	.0074
80	34	44	2–4/0	30	.0067
90	34	44	2–4/0	30	.0061
100	34	44	2–4/0	30	.0056

Sizes of Wires

For Continuous Current



Example—What size wire should be used to transmit 160 amperes a distance of 300 feet with 8 volts drop?

Solution—*From intersection of horizontal line for 8 volts drop, with diagonal for 300 feet distance, trace vertically upward to horizontal line for 160 amperes. The intersection falls on diagonal for 00 wire, which is the proper size to use.*

Sizes of Wires

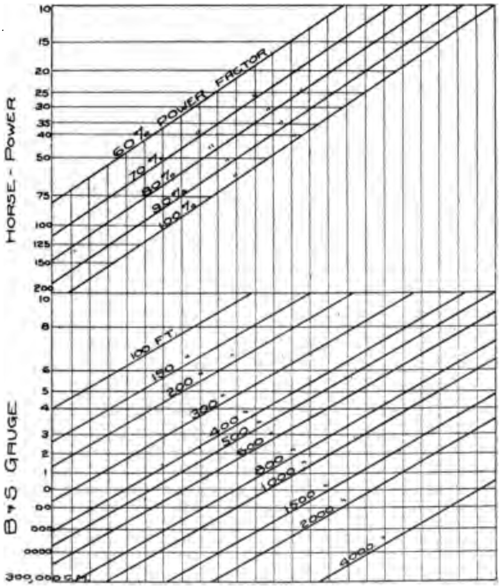
For 220-Volt, 3-Phase A. C. Circuits—10% Drop

This diagram does not pertain to the heating of wires.

On single-phase circuit the wire must have twice the area given by the diagram.

On 2-phase, 4-wire circuit the wire must be the same size as shown by the diagram.

On 440-volt circuit the distance that a given horsepower can be carried with 10% loss will be four times the value in the diagram; or the power can be made four times as large with the distance the same.



Example—What size wire should be used to transmit 25 horsepower at 220 volts, with 10% drop, on a 3-phase 3-wire line 1000 feet long, with an 80% power factor?

Solution—Starting at the upper left side at the point marked 25 Horsepower, go horizontally to the diagonal line marked *80% Power Factor*; thence vertically down to the line marked *1000 Ft.*; thence horizontally to the left, to find the required size of wire, namely, No. 1.

Formulas for

Transmission Line Calculations

These formulas, and the tables of Constants on the following page are based upon a spacing of 18 inches for the wires, and results are sufficiently accurate for practical purposes with wires approximately that distance apart. Capacity has been neglected.

ALTERNATING CURRENT:

Area of conductor, circular mils $= \frac{D \times W \times K}{P \times E^2}$

Current in each conductor, amperes $= \frac{W \times T}{E}$

Loss in lines, volts $= \frac{P \times E \times M}{100}$

Weight of Copper, pounds $= \frac{D^2 \times W \times K \times A}{P \times E^2 \times 1{,}000{,}000}$

Wherein:

A = Constant (See table, next page).

D = Distance of transmission, one way, in feet.

E = Voltage between main conductors at receiving or consumer's end of circuit.

K For any power factor = 2160 divided by the square of that power factor, for single phase.

= 2160 divided by twice the square of that power factor, for 2-phase, 4-wire and 3-phase, 3-wire.

M = Constant (See table, next page).

P = Loss in line, in percentage of power (W) delivered to consumer.

T = Constant (See table, next page).

W = Total watts delivered to consumer.

Power factors for balanced circuits—

Single phase: $\frac{\text{Actual watts delivered.}}{\text{Volts} \times \text{Amperes}}$

2-phase, 4-wire: $\frac{\text{Actual Watts, Total.}}{2 \times \text{Volts} \times \text{Amperes (per phase)}}$

3-phase, 3-wire: $\frac{\text{Actual Watts, Total.}}{1.73\ \text{Volts} \times \text{Amperes (per phase)}}$

OR DIRECT CURRENT: **A = 6.04, K = 2160, M = 1, T = 1.**

Constants for
Transmission Line Calculations

Phases	Wires	Values of A	Values of K				Values of T			
			Per Cent Power Factor				Per Cent Power Factor			
			100	95	85	80	100	95	85	80
1	....	6.04	2160	2400	3000	3380	1.00	1.05	1.17	1.25
2	4	12.08	1080	1200	1500	1690	.50	.53	.59	.62
3	3	9.06	1080	1200	1500	1690	.58	.61	.68	.72

Wire No., B. & S. Gauge	Values of M							
	25 Cycles				60 Cycles			
	Per Cent Power Factor				Per Cent Power Factor			
	95	90	85	80	95	90	85	80
0000	1.23	1.29	1.33	1.34	1.62	1.84	1.99	2.09
000	1.18	1.22	1.24	1.24	1.49	1.66	1.77	1.95
00	1.14	1.16	1.16	1.16	1.34	1.52	1.60	1.66
0	1.10	1.11	1.10	1.09	1.31	1.40	1.46	1.49
1	1.07	1.07	1.05	1.03	1.24	1.30	1.34	1.36
2	1.05	1.04	1.02	1.00	1.18	1.23	1.25	1.26
3	1.03	1.02	1.00	1.00	1.14	1.17	1.18	1.17
4	1.02	1.00	1.00	1.00	1.11	1.12	1.11	1.10
5	1.00	1.00	1.00	1.00	1.08	1.08	1.06	1.04
6	1.00	1.00	1.00	1.00	1.05	1.04	1.02	1.00
7	1.00	1.00	1.00	1.00	1.03	1.02	1.00	1.00
8	1.00	1.00	1.00	1.00	1.02	1.00	1.00	1.00
9	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Current Required for Motors

Amperes at Various Voltages

Horse Power of Motor	Efficiency* Per Cent	Watts Input	Amperes				
			110 Volts	220 Volts	250 Volts	500 Volts	550 Volts
1	65	1148	10.4	5.2	4.58	2.29	2.08
2	65	2295	20.8	10.4	9.16	4.58	4.16
2½	65	2870	26.0	13.0	11.45	5.72	5.21
3½	75	3481	31.6	15.8	13.9	6.90	6.32
5	75	4973	45.1	22.6	19.9	9.95	9.04
7½	80	6994	63.5	31.7	27.9	13.95	12.7
10	80	9325	84.6	42.3	37.2	18.6	16.9
15	85	13165	119.8	59.9	52.7	26.4	23.9
20	85	17553	159.6	79.8	70.2	35.1	31.9
25	90	20770	189.0	94.5	83.1	41.6	37.8
30	90	24864	225.8	112.9	99.4	49.7	45.2
40	90	33232	302.6	151.3	133.0	66.5	60.5
50	90	41540	378	189.0	166.2	83.1	75.6
75	90	62310	567	283.5	249.3	124.8	113.4
100	93	80215	729	364.3	320.5	160.3	145.7
125	93	100269	912	456	401	200.5	182.3
150	93	120322	1094	547	481	240.7	219
200	*94*	*158510*	1442	721	634	317	288

*Note—Efficiencies are taken arbitrarily. A variation in these percentages will make proportionate changes in watts and amperes.

Kilowatts and Horsepower

0.746 Kilowatts = 1 Horsepower

Kilowatts to Horsepower				Horsepower to Kilowatts			
Kw.	Horsepower	Kw.	Horsepower	Hp.	Kilowatts	Hp.	Kilowatts
1	1.341	55	73.733	1	.746	55	41.03
2	2.681	60	80.436	2	1.492	60	44.76
3	4.022	65	87.139	3	2.238	65	48.49
4	5.363	70	93.842	4	2.984	70	52.22
5	6.703	75	100.545	5	3.730	75	55.95
6	8.044	80	107.248	6	4.476	80	59.68
7	9.384	85	113.951	7	5.222	85	63.41
8	10.725	90	120.654	8	5.968	90	67.14
9	12.065	95	127.357	9	6.714	95	70.87
10	13.406	100	134.048	10	7.460	100	74.60
11	14.747	110	147.47	11	8.206	110	82.06
12	16.087	120	160.87	12	8.952	120	89.52
13	17.428	130	174.28	13	9.698	130	96.98
14	18.768	140	187.68	14	10.444	140	104.44
15	20.109	150	201.09	15	11.190	150	111.90
16	21.450	160	214.50	16	11.936	160	119.36
17	22.790	170	227.90	17	12.682	170	126.82
18	24.131	180	241.31	18	13.428	180	134.28
19	25.471	190	254.71	19	14.174	190	141.74
20	26.812	200	268.12	20	14.920	200	149.20
22	29.493	220	294.93	22	16.412	220	164.12
24	32.174	240	321.74	24	17.904	240	179.04
26	34.856	260	348.56	26	19.396	260	193.96
28	37.537	280	375.37	28	20.888	280	208.88
30	40.218	300	402.18	30	22.380	300	223.80
32	42.899	325	435.69	32	23.872	325	242.45
34	45.580	350	469.21	34	25.364	350	261.1
36	48.261	400	536.24	36	26.856	400	298.4
38	50.943	450	603.27	38	28.348	450	335.7
40	53.624	500	670.30	40	29.840	500	373.0
42	56.305	600	804.36	42	31.332	600	447.6
44	58.986	700	938.42	44	32.824	700	522.2
46	61.667	800	1072.48	46	34.316	800	596.8
48	64.349	900	1206.54	48	35.808	900	671.4
50	67.030	1000	1340.60	50	37.300	1000	746.0

Mechanical and Electrical Equivalents

Unit	Equivalent	Unit	Equivalent
1 heat unit B. T. U.	1 lb. water heated from 62° F. to 63° F. .001036 lbs. water evaporated from and at 212° F. .0000688 lbs. carbon oxidized. 1055 watt-seconds. 107.6 kilogram-meters. .000393 hp.-hours. 778 foot-pounds. .252 calories.	1 joule	1 watt-second. .000000278 kilowatt-hours. .102 kilogram-meters. .0009477 heat units. .7373 foot-pounds.
1 lb. water evaporated from and at 212° F.	970 heat units. 1019000 joules. 751300 foot-pounds. .283 kilowatt-hours. .379 hp.-hours. 103900 kilogram-meters.	1 watt	.001 kilowatts. 1 joule per second. .00134 horse power. .73 ft.-pounds per second. 44.24 ft.-lbs. per minute.
1 foot-pound	.001285 heat units. 1.356 joules. .1383 kilogram-meters. .000000377 kilowatt-hours. .0000005 hp.-hours.	1 kilogram-meter	7.233 foot-pounds. .00000365 hp.-hours. .00000272 kilowatt-hours. .0093 heat units.
1 hp.	33000 ft. lbs. per minute. 550 ft.-lbs. per second. 2545 heat units per hour 2.64 lbs. water evaporated per hour from and at 212° F. 746 watts. .746 kilowatts.	1 kilowatt	1000 watts. 1.34 horse power. 2654200 ft.-lbs. per hour. 44,240 ft.-lbs. per minute. 737.3 ft.-lbs. per second. 3412 heat units per hour. 56.9 heat units per minute. .948 heat units per second. 3.53 lbs. water evaporated from and at 212° F.
1 hp.-hour	1980000 foot-pounds. 2545 heat units. 2.64 lbs. water evaporated from and at 212° F. *17.0 lbs. water raised from 62° F. to 212° F.* *.746 kilowatt-hours.*	1 kilowatt-hour	1000 watt-hours. 1.34 hp.-hours. 2654200 ft.-lbs. 3600000 joules. 3412 heat units. 367000 kilogram-meters. 3.53 lbs. water evaporated from and at 212° F. 22.75 lbs. water raised from 62° F. to 212° F.

Metric and English Equivalents

1. To Convert Metric to English Units

Multiply	By	To Get
Centimeters	0.3937	Inches
Meters	3.2808	Feet
Meters	1.09361	Yards
Kilometers	0.62137	Miles
Square Centimeters	0.1550	Square Inches
Square Meters	10.7641	Square Feet
Square Kilometers	0.38611	Square Miles
Square Kilometers	247.114	Acres
Cubic Centimeters	0.0610	Cubic Inches
Cubic Meters	35.3140	Cubic Feet
Litres	0.2642	Gallons (American)
Kilograms	2.20462	Pounds (Avoirdupois)
Kilograms	0.001102	Tons (2000 Pounds)

2. To Convert English to Metric Units

Multiply	By	To Get
Inches	2.5001	Centimeters
Feet	0.3048	Meters
Yards	0.9144	Meters
Miles	1.60935	Kilometers
Square Inches	6.4516	Square Centimeters
Square Feet	0.0929	Square Meters
Square Miles	2.58899	Square Kilometers
Acres	0.004047	Square Kilometers
Cubic Inches	16.3934	Cubic Centimeters
Cubic Feet	0.02834	Cubic Meters
Gallons (American)	3.785	Litres
Pounds (Avoirdupois)	0.4536	Kilograms
Tons (2000 Pounds)	905.79	Kilograms

Mine Haulage

On level track the pulling force required to haul a load is that necessary to overcome the resistance due to track and equipment. In mine haulage these resistances vary in total between 1 percent and 2 percent of the train weight, the amount depending upon conditions of track, lubrication, etc.

On up grades another factor must be considered; namely, grade resistance, which is equal to that component of the total train weight acting downward and along the track. This grade resistance varies with the grade and, for a given percentage of grade, is equal to that same percentage of the train weight.

The adhesion between the locomotive wheels and the rails, effective for development of drawbar pull is:

Chilled cast iron wheels:

Dry rail with sand	25%	of weight on drivers
Dry rail without sand	20%	" " " "
Wet rail	5 to 15%	" " " "

Steel tired wheels:

Dry rail with sand	33%	of weight on drivers
Dry rail without sand	25%	" " " "
Wet rail	5 to 15%	" " " "

The resistances which affect the hauling power of a locomotive are:

1. Locomotive friction—gearing, bearing, flange, etc.:

For a new locomotive	20 lb. per ton of locomotive weight
For a locomotive worn into service	10 to 15 " " " " " "

2. Train friction and track condition.. 20 to 40 lb. per ton of train weight.
3. Grade.............. 20 lb. per ton of locomotive and train weight for each 1% of grade.

Friction and track resistances oppose the locomotive at all times and reduce its hauling capacity on the level and on grades. Grade resistance opposes the locomotive in ascending grades and assists it in descending. Total resistances therefore are: *On level and up grade, friction* resistance plus grade resistance; *down grade, friction* resistance minus grade resistance. Hence grade "resistance" be greater than friction resistance, the ain will run down grade without power. That is, if friction resistance is 30 lbs. per ton, the train will stand at rest on a 1 percent grade (20 lb. per ton grade resistance) and would run by gravity down a 2 percent grade (40 lb. per ton grade resistance).

Tractive effort and drawbar pull are not equal. Tractive effort measures the power of the locomotive as exerted by the wheels on the rails; drawbar pull is less than tractive effort by the amount of the locomotive resistance due to both friction and grade.

Drawbar Pull—To haul a given trainload on the level or up a grade:

$$D = W (F + G)$$

wherein,

D = drawbar pull, in pounds.
W = weight of train, in tons.
F = resistance of train due to friction, in pounds per ton of train weight.
G = resistance due to grade, 20 pounds for each 1 percent of grade.

EXAMPLE—Train weight, 60 tons; resistance due to friction, 30 lb. per ton; grade 2 percent. Then

$$D = 60 (30 + 40)$$
$$= 4200 \text{ lb.}$$

Tractive Effort—To haul a given trainload, including the locomotive itself, on the level or up a grade:

$$T = D + L (f + G)$$

wherein,

T = tractive effort, in pounds.
D = drawbar pull, in pounds.
L = weight of locomotive, in tons.
f = resistance of locomotive due to friction, in pounds per ton of weight.
G = resistance due to grade, 20 pounds for each 1 percent of grade.

EXAMPLE—Drawbar pull, 4200 lb.; locomotive weight, 15 tons; locomotive resistance due to friction, 15 lb. per ton; grade, 2 percent. Then

$$T = 4200 + 15 (15 + 40)$$
$$= 5025 \text{ lb.}$$

Weight of Locomotive—To haul a given trainload, on the level or up a grade:

$$L = W\frac{F+G}{(20\times A)-(f+G)}$$

wherein,

L = weight of locomotive, in tons.

W = weight of train, in tons.

F = resistance of train due to friction, in pounds per ton of train weight.

f = resistance of locomotive due to friction, in pounds per ton of locomotive weight.

G = resistance due to grade 20 pounds for each 1 percent of grade.

A = coefficient of track adhesion, in percentage of locomotive weight on drivers.

EXAMPLE— Train weight, 60 tons; train resistance due to friction, 30 lb. per ton; locomotive resistance due to friction, 15 lb. per ton; grade, 2 percent; adhesion, 25 percent. Then

$$L = 60\frac{30+40}{(20\times 25)-(15+40)}$$

= 9.66, or a 10-ton locomotive.

Horsepower—To develop a desired drawbar pull at given speed

$$H = D\times S\div 375$$

wherein,

H = horsepower.

D = drawbar pull, in pounds.

S = speed, in miles per hour.

EXAMPLE—Drawbar pull, 4200 lb.; speed, 6 miles per hour. Then

$$H = 4200\times 6\div 375$$

= 67.2 horsepower

On Heavy Grades

As the percentage of grade increases, the hauling capacity of a traction locomotive is seriously reduced, not only because of the increase of train resistance, but also because the effective drawbar pull of the locomotive is constantly reduced by the grade percentage of the weight of the locomotive itself.

Consider a locomotive with chilled wheels, at 20 percent adhesion. On level track the drawbar pull would be 400 pounds per ton of weight in the locomotive. On a grade this drawbar pull would be reduced by the grade resistance factor of the locomotive itself, or 20 pounds per ton of locomotive weight for very 1 percent of grade—a loss of 5 percent of drawbar pull for ery 1 percent of grade. On a 4 percent grade the level-track drawbar pull of 400 pounds per ton of locomotive weight is reduced by 20 percent, or 80 pounds, leaving 320 pounds of effective pulling force for train hauling. On a 10 percent grade the effective drawbar pull is reduced 50 percent, the remainder of the motive power being consumed in lifting the locomotive itself up the grade.

Hence the 10-ton locomotive which will haul 90 tons of train weight on level track will haul only 40 tons up a 2 percent grade, 23 tons up a 4 percent grade, 15 tons up a 6 percent grade, 10 tons up an 8 percent grade, and 6⅔ tons up a 10 percent grade.

This high rate of reduction of pulling force on grades is due largely to the lack of positive relation between the horsepower of the locomotive and the adhesion through which alone the motor power can be made effective in a traction locomotive. Where grades are encountered, therefore, a positive method of haulage is desirable, to make the motor horsepower fully available for pulling train load, avoiding the difficulties of traction haulage on grades and eliminating the excess dead weight which, in a traction locomotive, is necessary to give the required adhesion.

The Goodman Rack Rail Haulage system is positive, affording the desirable freedom from dependence on adhesion for pulling power and enabling effective realization of full motor power at all times, under all conditions, on the level or on grades. This system combines all the positiveness of the rope haul with the flexibility, safety, convenience and other advantages of locomotive operation. Where roadways are generally level and grades only local, the Combination Rack Rail and Traction system meets exactly the needs of the situation.

Operators whose mine haulage work involves grades should call upon the Goodman Manufacturing Co. for careful engineering advice as to the haulage system best suited to the conditions —traction, combined traction and rack rail, or plain rack rail. Supplying equipment of all types, the Goodman company can and will apply an unbiased and experienced judgment to the requirements of each individual case.

Types of Goodman Rack Rail Locomotives are illustrated *on pages 198* and 199.

Hauling Capacity of Mine Locomotives—Starting

Steel Tires or Steel Wheels. Clean Dry Rails and Sand.

Adhesion 33⅓% of Locomotive Weight.

Locomotive Weight, Tons	Tons of Net Train Weight (exclusive of the Locomotive)														
	Level Track			Up 1% Grade			Up 2% Grade			Up 3% Grade			Up 4% Grade		
	Car Friction, Pounds per Ton of Train Weight*														
	20	30	40	20	30	40	20	30	40	20	30	40	20	30	40
3	97	64	47	47	37	30	30	26	22	22	19	17	17	15	14
4	129	85	63	63	49	40	40	34	29	29	25	23	23	20	18
5	162	106	78	78	62	50	50	42	37	37	32	28	28	25	23
6	194	127	94	94	74	61	61	52	44	44	38	34	34	30	27
7	226	148	109	109	86	71	71	59	51	51	45	40	40	35	32
7½	243	159	118	118	93	76	76	64	55	55	48	43	43	38	34
8	258	170	125	125	99	81	81	68	59	59	51	48	48	40	36
10	323	212	156	156	123	101	101	85	73	73	64	57	57	51	45
11	355	233	172	172	135	111	111	93	80	80	70	63	63	55	50
13	420	275	203	203	160	132	132	111	95	95	83	74	74	65	59
15	485	318	234	234	185	161	161	127	110	110	96	85	85	76	68
20	646	424	312	312	246	202	202	170	146	146	128	114	114	102	90

*Car Friction is made up of journal resistance, track resistance, etc., the amount varying with the lubrication, and the condition of the equipment and track.

Hauling Capacity of Mine Locomotives—Running

Steel Tires or Steel Wheels. Clean Dry Rails

Adhesion 25% of Locomotive Weight.

Locomotive Weight, Tons	Tons of Net Train Weight (exclusive of the Locomotive)														
	Level Track			Up 1% Grade			Up 2% Grade			Up 3% Grade			Up 4% Grade		
	Car Friction, Pounds per Ton of Train Weight*														
	20	30	40	20	30	40	20	30	40	20	30	40	20	30	40
3	72	47	35	35	27	22	22	18	16	16	14	12	12	11	10
4	96	63	46	46	36	29	29	25	21	21	18	16	16	14	13
5	120	78	58	58	45	37	37	31	26	26	23	20	20	18	16
6	144	94	69	69	54	44	44	37	32	32	27	24	24	21	19
7	168	112	81	81	63	51	51	43	37	37	32	28	28	25	22
7½	180	118	86	86	68	55	55	46	39	39	34	30	30	27	24
8	192	125	92	92	71	59	59	49	43	43	36	32	32	28	25
10	240	156	116	116	90	74	74	62	52	52	46	40	40	36	32
11	264	173	127	127	99	80	80	68	58	58	50	44	44	39	35
13	312	214	150	150	117	95	95	80	69	69	59	52	52	46	41
15	360	235	172	172	135	110	110	92	77	77	68	60	60	53	48
20	480	313	230	230	180	146	146	123	105	105	91	80	80	71	63

*Car Friction is made up of journal resistance, track resistance, etc., the amount varying with the lubrication, and the condition of the equipment and track.

Hauling Capacity of Mine Locomotives—Starting

Chilled Cast Iron Wheels. Clean Dry Rails and Sand.

Adhesion 25% of Locomotive Weight.

Locomotive Weight, Tons	Tons of Net Train Weight (exclusive of the Locomotive)														
	Level Track			Up 1% Grade			Up 2% Grade			Up 3% Grade			Up 4% Grade		
	Car Friction, Pounds per Ton of Train Weight.*														
	20	30	40	20	30	40	20	30	40	20	30	40	20	30	40
3	72	47	35	35	27	22	22	18	16	16	14	12	12	11	10
4	96	63	46	46	36	29	29	25	21	21	18	16	16	14	13
5	120	78	58	58	45	37	37	31	26	26	23	20	20	18	16
6	144	94	69	69	54	44	44	37	32	32	27	24	24	21	19
7	168	112	81	81	63	51	51	43	37	37	32	28	28	25	22
7½	180	118	86	86	68	55	55	46	39	39	34	30	30	27	24
8	192	125	92	92	71	59	59	49	43	43	36	32	32	28	25
10	240	156	116	116	90	74	74	62	52	52	46	40	40	36	32
11	264	173	127	127	99	80	80	68	58	58	50	44	44	39	35
13	312	214	150	150	117	95	95	80	69	69	59	52	52	46	41
15	360	235	172	172	135	110	110	92	77	77	68	60	60	53	48
20	480	313	230	230	180	146	146	123	105	105	91	80	80	71	63

*Car Friction is made up of journal resistance, track resistance, etc., the amount varying with the lubrication, and the condition of the equipment and track.

Hauling Capacity of Mine Locomotives—Running

Chilled Cast Iron Wheels. Clean Dry Rails

Adhesion 20% of Locomotive Weight

Locomotive Weight, Tons	Tons of Net Train Weight (exclusive of the Locomotive)														
	Level Track			Up 1% Grade			Up 2% Grade			Up 3% Grade			Up 4% Grade		
	Car Friction, Pounds per Ton of Train Weight.*														
	20	30	40	20	30	40	20	30	40	20	30	40	20	30	40
3	57	37	27	27	21	17	17	14	12	12	10	9	9	8	7
4	76	49	36	36	28	23	23	19	16	16	14	12	12	11	9
5	95	61	45	45	35	28	28	24	20	20	17	15	15	13	12
6	114	74	54	54	42	34	34	28	24	24	21	18	18	16	14
7	133	86	63	63	49	38	38	33	28	28	24	21	21	18	16
7½	143	93	68	68	53	43	43	35	30	30	26	23	23	20	18
8	152	99	72	72	56	45	45	38	32	32	28	24	24	21	19
10	190	123	90	90	70	57	57	47	40	40	34	30	30	26	23
11	209	136	99	99	77	62	62	52	44	44	38	33	33	29	26
13	247	160	117	117	91	74	74	61	52	52	45	39	39	34	30
15	285	185	135	135	105	85	85	71	60	60	52	45	45	40	35
20	380	246	180	180	140	113	113	94	79	79	69	60	60	52	46

*Car Friction is made up of journal resistance, track resistance, etc., the amount varying with the lubrication, and the condition of the equipment and track.

Storage Battery Haulage

The ability of the Storage Battery Locomotive to operate over ordinary track, without trolley wiring or rail bonding, makes it very attractive for haulage work. In some mines storage battery locomotives have proved very successful, while in others presenting apparently similar conditions, they do not do so well. The difference in results is usually due to the difference in the handling and care which the locomotives and batteries receive.

The storage battery today is well known, and is a dependable device when properly selected for the work to be done, and properly handled. The care required to maintain it is not difficult, but happens to be of a different kind from that needed with other mine machinery with which men have long been familiar. With the designing of batteries better adapted for locomotive work, as brought on the market in recent years, and with the improvement in design of storage battery locomotives, the legitimate field of application of the battery locomotive has widened.

The developmental period has brought out several types of battery locomotives, which may be classed as follows:

Class A: Operated by storage battery only and which usually carry sufficient charge to last one working shift. Under conditions of excessive demand, boosting charges during the noon hour or other idle periods enable the locomotive to continue work during the full shift.

Class B: Operated by either battery or trolley.

Class C: Operated by battery or trolley as in Class B, but having in addition a charging rheostat and the necessary control apparatus on the locomotive to charge the battery while the motors are taking power from the trolley or while the trolley is on the wire.

Storage battery locomotives can be divided again into two groups, according to the method of their motoring:

Group 1: Single motor. Equipped with a low voltage motor to match conveniently the battery voltage. The scope of operation is limited by the capacity of the battery, as they cannot operate from the trolley. The speed is usually between three and four miles per hour at full running drawbar pull.

Group 2: Two motor. Equipped either with two low voltage motors, which are connected in series when operating from the trolley and in multiple when operating from the battery, or with two regular 250-volt railway motors, operating in multiple either from battery or trolley. The windings or designs in some cases are modified to take care of the lower voltage of the battery. With the latter plan the speed is usually considerably

Storage Battery Haulage—Continued

lower when operating on the battery than when running on the trolley, at the same drawbar pull.

Up to the present time the greatest application of storage battery locomotives has been for gathering in rooms and making comparatively short entry runs to convenient partings. Second in importance is entry gathering work, where the locomotives collect cars into trips on the entries and haul them to convenient partings at comparatively short distances.

A third application is for small main haulage work where the haulage is restricted either (a) by the total tonnage requirements, (b) by short grades, (c) by easy favorable grades, or (d) by short runs, so that the capacity of the work comes within the practical constructive limits of storage battery locomotives.

A fourth application uses the combination battery and trolley locomotive operating as a trolley locomotive on the longer runs or under the more difficult conditions. This is by far the largest field of application.

To meet the varying conditions to the best advantage, the Goodman Manufacturing Co. has developed the Articulated Storage Battery Locomotive, the motors of which are especially designed for the service and have split field control.

In gathering work the locomotive starts frequently and efficient control is necessary. The split fields reduce the rheostatic losses. The articulated construction permits the use of a battery as large as may be desired, yet without reducing the flexibility of the locomotive or detracting from its maneuvering ability. Thus the locomotive can have the greatest possible range, as a storage battery locomotive of Class A.

Where the hauls are longer or the duty more severe so that it becomes advisable to use trolley part of the time, the articulated locomotive is better adapted for combination work than other designs because its motors can be operated in series from the trolley. And by reason of the long motor wheelbase between the two trucks, the tractive ability of the locomotive is not reduced appreciably when the motors are operating in series. In the ordinary four-wheeled constructions with two motors it is practically impossible to obtain the maximum tractive effort with the motors connected in series by reason of the fact that one pair of drivers may slip more than the other.

Control of the Articulated locomotive is so arranged that a change from trolley to battery, or vice versa, is through *interlocking mechanism*, making mistakes impossible.

The speed of the locomotive when hauling its load shows less *difference between* battery and trolley operation than is found *with other forms* of control.

Storage Battery Haulage—Continued

Inasmuch as a large proportion of the weight in a storage battery locomotive is in the battery, the selection of a proper storage battery locomotive for a given service should be based primarily upon battery capacity and drawbar pull, rather than upon weight.

Storage batteries on locomotives are called upon to discharge, intermittently, currents in excess of the normal discharge rate. There is a decrease of efficiency as the discharge rate increases above normal, and consequently a decrease of the total kilowatt-hour capacity below what can be realized at normal rate of discharge.

Storage batteries have certain recuperative characteristics when allowed periods of rest or of low discharge rate between the periods of higher intermittent discharge rates, but in mining practice it is uncertain that the service can be planned to give these rest periods.

The less the maximum discharge rate exceeds the normal discharge rate, the longer will be the life of the battery. Safe and conservative locomotive practice dictates that the battery selected should be such that the maximum current called for by the motors will be a small multiple of the normal discharge rate.

Selection of a storage battery involves consideration of three factors and the striking of a proper balance among the three:

a. Maximum intermittent discharge **rate.**
b. Kilowatt-hours capacity.
c. Weight, bulk and cost of **battery.**

Storage Battery Data

Edison Batteries

Edison batteries should be charged at a constant rate throughout the entire period of charging.

Type and Size	Kilowatt Hours per Cell	Weight per Cell, Including Trays, Pounds	Normal Charging Time, Hours	Normal Discharging Time, Hours	Normal Rate of Charging and Discharging, Amperes	Normal Discharge, Ampere-Hours	Maximum Rate for Intermittent Discharge, Amperes
A- 8	0.360	29.5	7	5	60	300	300
A-10	.450	36.2	7	5	75	375	350
A-12	*.540*	44.8	7	5	90	450	400
G- 9	*.270*	*22*	4¾	3⅓	67½	225	337
G-11	*.330*	*30*	4¾	3⅓	82½	275	412
G-14	*.420*	*36*	4¾	3⅓	105	350	525
G-18	*.540*	*48*	4¾	3⅓	135	450	675

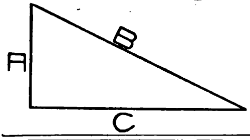
Storage Battery Data—Continued

Lead Batteries

Lead batteries should be charged at a diminishing rate, either (1) at a constant voltage of 2.3 volts per cell, in which case the rate will automatically diminish as the charging proceeds, or (2) by using the starting rate given below until the cells begin to gas, and then reducing to the finishing rate given below and continuing at this rate until charging is completed.

Number of Plates	Kilowatt-Hours per Cell	Weight per Cell, Including Trays, Pounds	Normal Charging Rate, Amperes		Normal Discharge, Ampere-Hours
			Start	Finish	
MVY Iron Clad Exide					
11	0.315	44	30	12	35
13	.378	51	35	14	42
15	.441	58	40	16	49
17	.504	65	45	18	56
19	.567	72	51	20	63
21	.630	78	56	22	70
23	.693	86	61	24	77
25	.756	93	66	26	84
MVY Exide					
11	0.2976	43.8	30	12	35
13	.357	50.8	35	14	42
15	.4166	58	40	16	49
17	.476	65.5	45	18	56
19	.5356	72	51	20	63
21	.595	78.5	56	22	70
23	.6546	86.3	61	24	77
25	.714	92.9	66	26	84
Philadelphia					
11	0.3	34.2	28	7	30
13	.36	40	34	9	36
15	.42	45.5	40	10	42
17	.48	51.7	45	12	48
19	.54	57.7	51	14	54
21	.6	63.5	56	15	60
23	.66	69.5	62	17	66
25	.72	75.5	68	19	72
27	.78	81.5	73	21	78
29	.84	87.2	78	23	84
31	.9	93	83	25	90
33	.96	98.7	88	27	9[illegible]

Percentage and Degrees of Grade



Ratio of Rise (A) to travel along the grade (B).

Ratio of rise (A) to horizontal projection (C) of travel along the grade.

Grade Per Cent	Angular Equivalent: Ratio of A to B: Degrees °	Minutes ′	Seconds ″	Ratio of A to C: Degrees °	Minutes ′	Seconds ″
1	0	34	22.8	0	34	22.8
2	1	8	45.5	1	8	45.5
3	1	43	8.3	1	43	6.2
4	2	17	33.1	2	17	26.9
5	2	51	58.0	2	51	45.5
6	3	26	22.8	3	26	2.0
7	4	0	49.6	4	0	14.5
8	4	35	18.6	4	34	26.0
9	5	9	49.6	5	8	34.0
10	5	44	20.7	5	42	38.0
12	6	53	31.1	6	50	34.0
14	8	2	51.8	7	58	10.3
16	9	12	24.8	9	5	24.8
18	10	22	10.7	10	12	14.0
20	11	32	12.9	11	18	36.0
22	12	42	32.2	12	24	27.1
24	13	53	10.7	13	29	44.5
26	15	4	12.8	14	34	27.1
28	16	15	36.4	15	38	31.9
30	17	27	27.8	16	41	58.0
35	20	29	15.0	19	17	23.6
40	23	34	41.5	21	48	5.3
45	26	44	36.9	24	13	39.4
50	30	0	0.0	26	33	53.4
55	33	22	2.4	28	48	39.5
60	36	52	12.5	30	57	49.5
65	40	32	30.0	33	1	25.7
70	44	25	37.2	34	59	31.4
75	48	35	25.3	36	52	11.7
80	53	7	49.4	38	39	35.0
90	64	9	27.7	41	59	13.8
100	90	0	0.0	45	0	0.0

Rail Weights to Use

For Locomotives with Four or Six Wheels

Weight of Locomotive, Tons	Weight of Rail, Pounds per Yard			
	Four-Wheel Locomotive		Six-Wheel Locomotive	
	Minimum	Recommended	Minimum	Recommended
3	16	20	....	....
4	16	25	....	....
5	16	25	....	....
6	20	30	....	....
7	20	30	....	....
8	25	30	....	....
10	30	40	20	30
12	30	45	20	30
13	30	50	25	40
15	40	50	30	40
20	50	60	40	50
25	60	70	50	60
30	75	80	60	70

The table is based approximately upon the allowance of 10 pounds of rail weight per yard, per ton of locomotive weight on each driving wheel, for minimum rail section. For example, the minimum rail weight for a 10-ton 4-wheel locomotive is

$$10 \times 10 \div 4 = 25 \text{ pounds per yard}$$

The table values are approximate only, as the proper size or *weight of rail* must be determined with due consideration also *of the nature* of the roadbed, the spacing of the ties, the gener *construction* and the horsepower of the motors.

Elevation of Outer Rail at Curves

For 36-Inch Track Gauge

Radius of Curve, Feet	Speed, Miles per Hour								
	4	5	6	8	10	12	15	20	30
	Elevation of Outer Rail, Inches								
8	4.81	7.48	.....	.....	.....	.....	.....	.....	.....
10	3.85	5.99	8.54	.....	.....	.....	.....	.....	.....
12	3.22	4.99	7.11	12.74	.....	.....	.....	.....	.....
14	2.75	4.28	6.09	10.96	.....	.....	.....	.....	.....
16	2.40	3.75	5.31	9.49	14.07	.....	.....	.....	.....
18	2.14	3.33	4.75	8.47	13.34	.....	.....	.....	.....
20	1.92	2.99	4.27	7.70	12.00	.....	.....	.....	.....
25	1.54	2.39	3.42	6.13	9.59	13.80	.....	.....	.....
30	1.30	2.00	2.84	5.10	8.00	11.46	.....	.....	.....
35	1.10	1.71	2.43	4.38	6.86	9.85	.....	.....	.....
40	.960	1.51	2.13	3.84	6.00	8.61	13.50	.....	.....
45	.853	1.33	1.90	3.40	5.32	7.64	11.95	.....	.....
50	.771	1.19	1.71	3.06	4.80	6.89	10.75	.....	.....
60	.644	.993	1.42	2.56	4.00	5.75	9.00	.....	.....
80	.479	.751	1.06	1.93	3.00	4.32	6.75	11.95	.....
100	.385	.598	.854	1.53	2.40	3.44	5.39	9.55	.....
150	.....	.399	.568	1.03	1.60	2.30	3.60	6.37	12.30
200	.....	.300	.427	.765	1.21	1.72	2.70	4.78	10.75
300	.....	.....	.284	.511	.800	1.15	1.80	3.18	7.20
400	.....	.....	.....	.384	.600	.860	1.35	2.39	5.38
500	.....	.....	.....	.....	.480	.687	1.08	1.91	4.31
1000	.....	.....	.....	.....	.....	.....	.269	.478	1.08

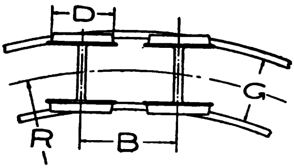
The above values are for 36-inch gauge.

For any other gauge, multiply the value in the table by that gauge and divide by 36.

EXAMPLE.—How much higher should the outer rail be on a 42-inch gauge track if the radius of the curve is 45 ft. and the locomotive is to round the curve at 8 miles per hour?

SOLUTION.—The table gives the elevation 3.40 in. for 36-inch gauge. Hence for 42-inch gauge the elevation should be 42 x 3.40 ÷ 36 = 3.97, or 4 inches.

Minimum Radius of Curve



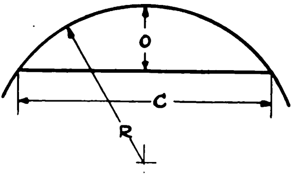
For Operation of Locomotives with Given Wheel Sizes and Wheel Bases

Assuming that the gauge (G) is increased the proper amount at curves, usually about one inch.

Wheel Base, Inches, B	Diameter of Wheel, Inches—D 18	20	24	30	33	36
	Minimum Radius of Curve, Feet—R					
20½	8	8	....	....	....	....
24	8	8	....	....	....	....
24¾	8	9	10	....	....	....
27¼	9	10	11	....	....	....
30	9	11	12	....	....	....
32	10	12	13	14	....	....
34	11	12	14	15	16	....
36	11	13	15	16	17	17
38	12	13	15	17	18	18
40	13	14	16	17	18	19
42	14	15	17	18	19	20
44	14	16	17	19	20	21
46	15	17	18	19	21	21
48	16	18	19	20	22	22
50	16	18	20	21	23	23
52	17	19	20	22	24	24
54	17	19	21	23	25	25
56	18	20	22	24	26	26
58	19	20	23	25	27	27
60	19	21	23	25	28	28
62	20	21	24	26	29	29
64	20	22	25	27	29	30
66	21	22	25	28	30	30
68	22	23	26	29	31	32
70	22	24	27	30	32	33

Curvature of Track Rails

Middle ordinates for curves of various radii, on chords of various lengths.



$R = 36 C^2 + O^2 \div 24 O$

wherein

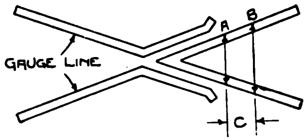
R = Radius of curvature in feet

C = Length of chord in feet

O = Middle ordinate in inches.

Radius (R) Feet	Length of Chord (C), Feet						
	5	10	15	20	25	30	50
	Height of Middle Ordinate (O), Inches						
4	10.53	......	......	......	......	......	......
5	8.04	60.00	......	......	......	......	......
6	6.55	32.20	......	......	......	......	......
7	5.54	25.21	......	......	......	......	......
8	4.81	21.06	62.59	......	......	......	......
9	4.25	18.20	48.30	......	......	......	......
10	3.81	16.08	40.63	120.00	......	......	......
12	3.16	13.19	31.64	64.40	......	......	......
15	2.52	10.29	24.12	45.84	80.50	180.00	......
20	1.88	7.62	17.51	32.15	52.65	81.25	......
25	1.40	6.06	13.82	25.05	40.19	60.00	300.00
30	1.25	5.04	11.43	20 59	32.74	48.23	161.00
50	.75	3.01	6.79	12.12	19.05	27.64	80.39
75	......	2.00	4.51	8.04	12.59	18.18	51.47
100	......	1.50	3.38	6.02	9.41	13.58	38.10
125	......	1.20	2.70	4.81	7.52	10.84	30.31
150	......	1.00	2.25	4.00	6.26	9.02	25.18
200	......	.75	1.69	3.00	4.69	6.76	18.82
250	......	.60	1.35	2.40	3.75	5.40	15.04
500	......	.30	.68	1.20	1.88	2.70	7.50
750	......	.20	.45	.80	1.25	1.80	5.00
1000	......	.15	.34	.60	.94	1.35	3.75

Frogs and Switches



1. Frog Number

The number of a frog is determined by the degree of its spread —the angle at which the gauge lines cross.

The number of inches in which the spread of the gauge lines increases one inch is assigned as the number of the frog. Hence:

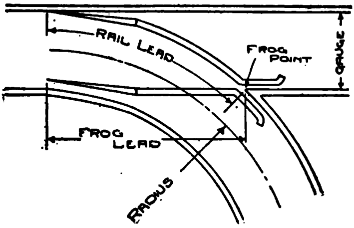
To find the Number of any Frog: Measure across the frog point at a place (A) where the distance between the gauge lines is even inches or some convenient fraction; measure again where the distance is an inch greater (B) than at A; the number of inches (C) between the two measurements (A and B) is the number of the frog.

EXAMPLE— Measurement at A=2 inches; at B=3 inches; distance C=2 inches. Then the frog is a No. 2.

Frog Spreads and Angles

Frog No.	Spread per foot, Inches	Frog Angle	Frog No.	Spread per foot, Inches	Frog Angle
1	12.00	53° 8″	3	4.00	18° 55″
1¼	9.60	43° 36″	3¼	3.69	17° 30″
1½	8.00	36° 52″	3½	3.43	16° 16″
1¾	6.86	31° 54″	3¾	3.20	15° 11″
2	6.00	28° 4″	4.	3.00	14° 15″
2¼	5.33	25° 3″	4¼	2.82	13° 25″
2½	4.80	22° 37″	4½	2.67	12° 41″
2¾	4.36	20° 37″	5	2.40	11° 25″

Frogs and Switches—Continued



2. Frog Lead—Straight Rail

(Table, Page 48)

Frog lead is the distance from switch point to frog point, measured along the straight track.

It is equal to twice the track gauge, multiplied by the frog number. Since frog lead is usually wanted in feet, while gauge is usually expressed in inches, the formula becomes:

$$L = G \times N \div 6$$

wherein,

L = Frog lead in feet.
G = Track gauge in inches.
N = Number of frog.

Example—Track gauge, 36 in.; frog No. 2. Then

$$\text{Frog lead} = 36 \times 2 \div 6 = 12 \text{ ft.}$$

3. Rail Lead—Curved Rail

(Illustration above. Table, page 49)

The length of curved rail from switch point to frog point, corresponding to the frog lead for a given track gauge, is given with close approximation by the formula:

$$C = (\sqrt{G^2 + 144\ L^2} - 3\ L) \div 9$$

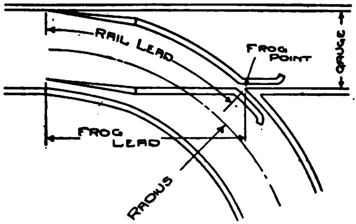
wherein,

C = Curved rail lead in feet.
G = Track gauge in inches.
L = *Frog* lead in feet.

Example—Track gauge 30 in.; frog lead 12 ft. Then

$$\textit{Curved rail lead} = (\sqrt{900 + (144 \times 144)} - 36) \div 9$$
$$= 12.34 \text{ ft.} = 12 \text{ ft. } 4 \text{ in.}$$

Frogs and Switches—Continued



4. Radius of Curve

For a Given Gauge and Frog

(Table, page 50)

The radius of curvature, measured at center line of track, is equal to twice the track gauge multiplied by the square of the frog number. To get radius in feet, using track gauge in inches, the formula is:

$$R = G \times N^2 \div 6$$

wherein,
R = Radius of curve in feet.
G = Track gauge in inches.
N = Number of frog.

EXAMPLE—Track gauge 36 in.; frog No. 2. Then

$$\text{Radius} = 36 \times 4 \div 6 = 24 \text{ ft.}$$

5. Frog to Use

For a Given Gauge and Radius

(Illustration above, Table, page 51)

Transposing the radius formula above we have for frog number:

$$N^2 = 6 \times R \div G$$

EXAMPLE—Track gauge, 36 in.; radius of curve, 24 ft. Then

$$N^2 = 6 \times 24 \div 36 = 4$$

and

$$N = 2$$

Frogs and Switches—Continued

2. Frog Lead Lengths

(Formula and Illustration, page 46)

Frog No.	Track Gauge, Inches: 18	20	22	24	26	28	30	36	40	42	44	48	56½
	Frog Lead, Feet and Inches												
1	3′ 0″	3′ 4″	3′ 8″	4′ 0″	4′ 4″	4′ 8″	5′ 0″	6′ 0″	6′ 8″	7′ 0″	7′ 4″	8′ 0″	9′ 5″
1¼	3′ 9″	4′ 2″	4′ 7″	5′ 0″	5′ 5″	5′10″	6′ 3″	7′ 6″	8′ 4″	8′ 9″	9′ 2″	10′ 0″	11′ 9¼″
1½	4′ 6″	5′ 0″	5′ 6″	6′ 0″	6′ 6″	7′ 0″	7′ 6″	9′ 0″	10′ 0″	10′ 6″	11′ 0″	12′ 0″	14′ 1½″
1¾	5′ 3″	5′10″	6′ 5″	7′ 0″	7′ 7″	8′ 2″	8′ 9″	10′ 6″	11′ 8″	12′ 3″	12′10″	14′ 0″	16′ 5¾″
2	6′ 0″	6′ 8″	7′ 4″	8′ 0″	8′ 8″	9′ 4″	10′ 0″	12′ 0″	13′ 4″	14′ 0″	14′ 8″	16′ 0″	18′10″
2¼	6′ 9″	7′ 6″	8′ 3″	9′ 0″	9′ 9″	10′ 6″	11′ 3″	13′ 6″	15′ 0″	15′ 9″	16′ 6″	18′ 0″	21′ 2¼″
2½	7′ 6″	8′ 4″	9′ 2″	10′ 0″	10′10″	11′ 8″	12′ 6″	15′ 0″	16′ 8″	17′ 6″	18′ 4″	20′ 0″	23′ 6½″
2¾	8′ 3″	9′ 2″	10′ 1″	11′ 0″	11′11″	12′10″	13′ 9″	16′ 6″	18′ 4″	19′ 3″	20′ 2″	22′ 0″	25′10¾″
3	9′ 0″	10′ 0″	11′ 0″	12′ 0″	13′ 0″	14′ 0″	15′ 0″	18′ 0″	20′ 0″	21′ 0″	22′ 0″	24′ 0″	28′ 3″
3¼	9′ 9″	10′10″	11′11″	13′ 0″	14′ 1″	15′ 2″	16′ 3″	19′ 6″	21′ 8″	22′ 9″	23′10″	26′ 0″	30′ 7¼″
3½	10′ 6″	11′ 8″	12′10″	14′ 0″	15′ 2″	16′ 4″	17′ 6″	21′ 0″	23′ 4″	24′ 6″	25′ 8″	28′ 0″	32′11½″
3¾	11′ 3″	12′ 6″	13′ 9″	15′ 0″	16′ 3″	17′ 6″	18′ 9″	22′ 6″	25′ 0″	26′ 3″	27′ 6″	30′ 0″	35′ 3¾″
4	12′ 0″	13′ 4″	14′ 8″	16′ 0″	17′ 4″	18′ 8″	20′ 0″	24′ 0″	26′ 8″	28′ 0″	29′ 4″	32′ 0″	37′ 8″
4¼	12′ 9″	14′ 2″	15′ 7″	17′ 0″	18′ 5″	19′10″	21′ 3″	25′ 6″	28′ 4″	29′ 9″	31′ 2″	34′ 0″	40′ ¼″
4½	13′ 6″	15′ 0″	16′ 6″	18′ 0″	19′ 6″	21′ 0″	22′ 6″	27′ 0″	30′ 0″	31′ 6″	33′ 0″	36′ 0″	42′ 4½″
5	15′ 0″	16′ 8″	18′ 4″	20′ 0″	21′ 8″	23′ 4″	25′ 0″	30′ 0″	33′ 4″	35′ 0″	36′ 8″	40′ 0″	47′ 1″

Frogs and Switches—Continued

3. Curved Rail Lead Lengths

(Formula and Illustration, page 46)

Frog Lead, Feet	Track Gauge, Inches												
	18	20	22	24	26	28	30	36	40	42	44	48	56½
	Curved Rail Lead, Feet												
3	3′ 5¾″	3′ 7½″	3′ 9¼″	3′11″	4′ 1″	4′ 3″	4′ 5¼″	5′ 0″	5′ 4½″	5′ 7″	5′ 9½″	6′ 3″	7′ 3½″
6	6′ 3″	6′ 3½″	6′ 4″	6′ 4¾″	6′ 5½″	6′ 6½″	6′ 7½″	6′11¼″	7′ 1¾″	7′ 3¼″	7′ 5½″	7′10″	8′ 6¾″
9	9′ 1¾″	9′ 2″	9′ 2½″	9′ 3″	9′ 3½″	9′ 4¼″	9′ 5″	9′ 7½″	9′ 9¼″	9′10¼″	9′11¼″	10′ 1¼″	10′ 7¾″
12	12′ 1¾″	12′ 2″	12′ 2¼″	12′ 2½″	12′ 3″	12′ 3½″	12′ 4″	12′ 5¾″	12′ 7″	12′ 7¾″	12′ 8½″	12′10″	13′ 2¼″
15	15′ 1¼″	15′ 1½″	15′ 1¾″	15′ 2″	15′ 2½″	15′ 3″	15′ 3½″	15′ 4¾″	15′ 6¼″	15′ 6¾″	15′ 7¼″	15′ 8½″	15′11½″
18	....	18′ 1½″	18′ 1¾″	18′ 2″	18′ 2¼″	18′ 2½″	18′ 2¾″	18′ 3½″	18′ 4½″	18′ 5″	18′ 5¾″	18′ 7¼″	18′ 9″
21	....	....	....	21′ 1¾″	21′ 2″	21′ 2″	21′ 2½″	21′ 3¼″	21′ 4¼″	21′ 4¼″	21′ 5¼″	21′ 6″	21′ 7¾″
24	....	....	....	....	....	....	24′ 2¼″	24′ 3″	24′ 3½″	24′ 3¾″	24′ 4¼″	24′ 4¾″	24′ 6½″
27	....	....	....	....	....	....	....	27′ 2¾″	27′ 3″	27′ 3¼″	27′ 3½″	27′ 4¼″	27′ 5¾″
30	....	....	....	....	....	....	....	30′ 2½″	30′ 2¼″	30′ 2½″	30′ 3¼″	30′ 4¼″	30′ 5″
33	....	....	....	....	....	....	....	....	33′ 2″	33′ 2½″	33′ 3″	33′ 4¼″	33′ 5″
36	....	....	....	....	....	....	....	....	....	....	36′ 2″	36′ 3¾″	36′ 4¾″
39	....	....	....	....	....	....	....	....	....	....	....	39′ 3″	39′ 4¾″
42	....	....	....	....	....	....	....	....	....	....	....	42′ 2½″	42′ 4¾″
	....	....	....	....	....	....	....	....	....	....	....	....	45′ 3½″

Frogs and Switches—Continued

4. Radius of Curve

(Formula and Illustration, page 47)

Frog No.	Track Gauge, Inches												
	18	20	22	24	26	28	30	36	40	42	44	48	56½
	Radius of Curve, Center of Track, Feet												
1	3' 0"	3' 4"	3' 8"	4' 0"	4' 4"	4' 8"	5' 0"	6' 0"	6' 8"	7' 0"	7' 4"	8' 0"	9' 5"
1¼	4' 8¼"	5' 2½"	5' 8¾"	6' 3"	6' 9¼"	7' 3½"	7' 9¾"	9' 4½"	10' 5"	10'11¼"	11' 5½"	12' 6"	14' 8½"
1½	6' 9"	7' 6"	8' 3"	9' 0"	9' 9"	10' 6"	11' 3"	13' 6"	15' 0"	15' 9"	16' 6"	18' 0"	21' 2¼"
1¾	9' 1¾"	10' 2¾"	11' 3"	12' 3"	13' 3¼"	14' 3½"	15' 3¾"	18' 4½"	20' 5"	21' 5¼"	22' 5½"	24' 6"	28'10"
2	12' 0"	13' 4"	14' 9"	16' 0"	17' 4"	18' 8"	20' 0"	24' 0"	26' 8"	28' 0"	29' 4"	32' 0"	37' 8"
2¼	15' 1¾"	16'10¼"	18' 7¼"	20' 1¾"	21'11¼"	23' 7½"	25' 3¾"	30' 4½"	33' 9"	35' 5¼"	37' 1½"	40' 6"	47' 6"
2½	18' 9"	20'10¼"	22'11½"	25' 0"	27' 1"	29' 2"	31' 3"	37' 6"	41' 8"	43' 9"	45'10"	50' 0"	58'10¼"
2¾	22' 7¾"	25' 2½"	27' 9½"	30' 3½"	32' 9¼"	35' 3½"	37' 9¾"	45' 4½"	50' 5"	52' 9¼"	55' 5½"	60' 6"	71' 2½"
3	27' 0"	30' 0"	33' 0"	36' 0"	39' 0"	42' 0"	45' 0"	54' 0"	60' 0"	63' 0"	66' 0"	72' 0"	84'11"
3¼	31' 7¾"	35' 1¼"	38' 9"	42' 3"	45' 9¼"	49' 3½"	52' 3¾"	63' 4½"	70' 5"	73'11¼"	77' 5½"	84' 6"	99' 5½"
3½	37' 9½"	40' 9"	44'10¾"	49' 0"	53'10"	57' 2"	61' 3"	73' 6"	81' 8"	85' 9"	89'10"	98' 0"	115'4¼"
3¾	42' 3"	46' 9"	51' 6"	56' 3"	60'11¼"	65' 7½"	70' 3¾"	84' 4½"	93' 9"	98' 5¼"	103'1½"	112'6"	132'5"
4	48' 0"	53' 4"	58' 8"	64' 0"	69' 3"	74' 8"	80' 0"	96' 0"	106'8"	112'0"	117'4"	128'0"	150'8"
4¼	54' 3"	60' 3"	66' 3"	72' 3"	78' 3¼"	84' 3½"	90' 3¾"	108'4½"	120'5"	126'5¼"	132'5½"	144'6"	170'1"
4½	60' 9"	67' 6"	74' 3"	81' 0"	87' 9"	94' 6"	101'3"	121'6"	135'0"	141'9"	148'6"	162'0"	190'8¼"
5	75' 0"	83' 4"	91' 8"	100'0"	108'3"	116'8"	125'0"	150'0"	166'8"	175'0"	183'4"	200'0"	235'5"

Frogs and Switches—Continued

5. Frog to Use

For a Given Gauge and Radius

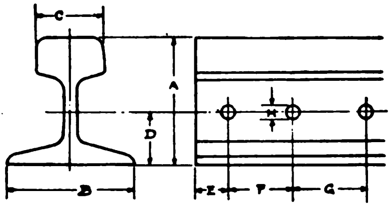
(Formula and Illustration, page 47)

Radius of Curve, Feet	Track Gauge, Inches												
	18	20	22	24	26	28	30	36	40	42	44	48	56½
	No. of Frog to Use												
5	1¼	1¼	1¼	1¼	1	1	1	1	1	....	....	....	....
6	1½	1¼	1¼	1¼	1¼	1¼	1	1	1	1	1	....	....
7	1½	1½	1¼	1¼	1¼	1¼	1¼	1	1	1	1	1	....
8	1¾	1½	1½	1½	1¼	1¼	1¼	1¼	1	1	1	1	1
9	1¾	1¾	1½	1½	1½	1½	1¼	1¼	1¼	1¼	1	1	1
10	1¾	1¾	1¾	1½	1½	1½	1¼	1¼	1¼	1¼	1¼	1	1
12	2	2	1¾	1¾	1¾	1½	1½	1½	1¼	1¼	1¼	1¼	1¼
14	2¼	2	2	1¾	1¾	1¾	1¾	1½	1½	1½	1½	1¼	1¼
16	2¼	2¼	2	2	2	1¾	1¾	1¾	1½	1½	1½	1½	1¼
18	2½	2¼	2¼	2¼	2	2	2	1¾	1¾	1½	1½	1½	1½
20	2½	2½	2¼	2¼	2¼	2	2	1¾	1¾	1¾	1¾	1½	1½
22	2¾	2½	2½	2¼	2¼	2¼	2	2	1¾	1¾	1¾	1¾	1½
24	2¾	2¾	2½	2½	2¼	2¼	2¼	2	2	1¾	1¾	1¾	1½
26	3	2¾	2¾	2½	2½	2¼	2¼	2	2	2	2	1¾	1¾
28	3	3	2¾	2¾	2½	2½	2¼	2¼	2	2	2	1¾	1¾
30	3¼	3	3	2¾	2¾	2½	2½	2¼	2¼	2	2	2	1¾
32	3¼	3	3	2¾	2¾	2½	2½	2¼	2¼	2¼	2	2	1¾
36	3½	3¼	3	3	3	2¾	2¾	2½	2¼	2¼	2	2	2
40	3¾	3½	3¼	3¼	3	3	2¾	2½	2½	2¼	2¼	2¼	2
44	3¾	3¾	3½	3¼	3¼	3	3	2¾	2½	2½	2½	2¼	2¼
48	4	3¾	3½	3½	3¼	3¼	3	2¾	2¾	2½	2½	2½	2¼
54	4¼	4	3¾	3¾	3½	3½	3¼	3	2¾	2¾	2¾	2½	2½
60	4½	4¼	4	3¾	3¾	3½	3½	3¼	3	3	2¾	2¾	2½
66	4¾	4½	4¼	4	4	3¾	3¾	3½	3¼	3	3	2¾	2¾
72	5	4¾	4½	4¼	4	4	3¾	3½	3¼	3¼	3¼	3	2¾
78	5	4¾	4¾	4½	4¼	4	4	3¾	3½	3¼	3¼	3¼	3
84	5¼	5	4¾	4½	4½	4¼	4	3¾	3½	3½	3½	3¼	3
90	5½	5¼	5	4¾	4½	4½	4¼	4	3¾	3½	3½	3¼	3

Dimensions of

Rail Sections and Drilling

A. S. C. E. Standard



Rail, Weight, Pounds per Yard	Dimensions, Inches							Weight of Single Track, Short Tons per 1000 Feet
	Rail			Drilling*				
	A	B	C	D	E	F	H	
8	1 1/2	1 1/2	13/16	79/128	2	4	3/4	2.67
12	1 7/8	1 7/8	1 1/16	101/128	2	4	3/4	3.67
16	2 1/4	2 1/4	1 1/4	1 3/128	2	4	3/4	5.33
20	2 1/2	2 1/2	1 3/8	1 15/128	2	4	3/4	6.67
25	2 3/4	2 3/4	1 1/2	1 29/128	2	4	3/4	8.33
30	3	3	1 5/8	1 43/128	2	4	3/4	10.0
35	3 1/4	3 1/4	1 3/4	1 57/128	2	4	3/4	11.66
40	3 1/2	3 1/2	1 7/8	1 71/128	2	4	7/8	13.33
45	3 11/16	3 11/16	2	1 41/64	2	4	7/8	15.00
50	3 7/8	3 7/8	2 1/8	1 23/32	2 7/16	5	7/8	16.66
55	4 1/16	4 1/16	2 1/4	1 101/128	2 7/16	5	7/8	18.33
60	4 1/4	4 1/4	2 3/8	1 115/128	2 3/8	5	1	20.00
65	4 7/16	4 7/16	2 13/32	1 31/32	2 3/8	5	1	21.66
70	*4 5/8*	4 5/8	2 7/16	2 3/64	2 3/8	5	1	23.33

*Rails 65 lbs. and lighter have only two holes; hence no dimension G. For 70-lb. rail, G = F = 5 in.

Rails, Splices, Bolts and Spikes

Per 1,000 Feet of Single Track

Rails, Splices and Bolts

Rail Length, Feet	Number of Rails	Number of Splices	Number of Bolts	
			4 per Joint	6 per Joint
18	111	222	888	1332
20	100	200	800	1200
22	91	182	728	1092
25	80	160	640	960
27	74	148	592	888
30	67	134	536	804

Spikes

Ties Spaced 2 ft. on Centers; 4 Spikes per Tie.

Spike Size Under Head, Inches	Average Number per Keg of 200 pounds	Spikes per 1000 Feet of Single Track		Rail Weights, Pounds per Yard
		Pounds	Kegs	
2½x⅜	1650	243	1¼	12 to 16
3 x⅜	1380	295	1½	16 to 20
3½x⅜	1250	325	1⅝	16 to 20
4 x⅜	1025	395	2	16 to 25
3½x7/16	890	455	2⅜	16 to 25
4 x7/16	780	515	2⅝	20 to 30
4½x7/16	690	585	3	20 to 30
4 x½	605	665	3⅜	24 to 35
4½x½	518	775	3⅞	28 to 35
5 x½	475	850	4¼	35 to 40
5 x9/16	*405*	995	5	40 to 56
5½x9/16	*360*	1120	5⅝	45 to 70

Mine Hoisting

The six diagrams on pages 56 to 61 are for use in connection with hoisting engines of direct connected, or first motion type.

1. Rope Speeds. Page 56.

EXAMPLE—What will be the rope speed if the engine stroke is 30 in., the piston speed 800 ft. per minute, and the diameter of the drum 4 ft.?

SOLUTION—Starting at the top of the diagram, at the line for 800 ft. per minute, trace vertically down to the diagonal for 30-in. stroke; thence horizontally to the diagonal for 4-ft. drum; thence vertically down to the bottom, to find the rope speed—2100 ft. per minute.

2. Drum Capacities. Page 57.

EXAMPLE—How many feet of ¾-in. rope will wind in one layer on a 6-ft. cylindrical drum with a 2-ft. ungrooved face?

SOLUTION—Starting at the top of the diagram, at the line for 6-ft. drum diameter, trace vertically down to the diagonal for ¾-in. rope; thence horizontally to the diagonal for 2-ft. face; thence vertically down to the bottom, to find the length of rope—590 ft.

3. Ropes in Multiple Layers. Page 58.

EXAMPLE—What length and weight of 1-in. rope will there be in 3 layers on a 9-ft. drum having a 2-ft. face?

SOLUTION—Starting at the top of the diagram, at the line for 9-ft. drum diameter, trace vertically down to the diagonal for 1-in. rope; thence horizontally to the diagonal for 3 layers; and thence vertically down to the center of the diagram, to find the length of rope—1000 ft. per foot of face, which, multiplied by the face width in feet, gives 2000 ft. Continuing vertically down to the diagonal for 1-in. rope, and thence horizontally to the right, the weight will be found—1600 lb. per foot of face, or 3200 lbs. for the 2-ft. face.

Mine Hoisting—Continued

4. Load Capacities. Page 59.

EXAMPLE—What vertical unbalanced load can a 28 x 36-in. engine handle, if it has a 6-ft. drum, and is running on 80 lbs. steam pressure?

SOLUTION—Starting at the top of the diagram, at the line for 28-in. cylinder diameter, trace vertically down to the diagonal for 36-in. stroke; thence horizontally to the diagonal for 80 lbs. steam; thence vertically down to the curve for 6-ft. drum diameter; and thence horizontally to the left side, to find the vertical unbalanced load—14,200 lbs.

5. Rates of Hoisting. Page 60.

EXAMPLE—How many cars per hour can be handled in a shaft 600 ft. deep, if the average speed of the rope is 1500 ft. per minute and the time required to change or dump cars is 25 seconds?

SOLUTION—Starting at the top of the diagram, at the line for 600 ft. shaft depth, trace vertically down to the straight diagonal for 1500-ft. rope speed; thence horizontally to the curved diagonal for 25 seconds; and thence to the bottom to find the capacity—74 cars per hour.

6. Hoisting on Inclines. Page 61.

EXAMPLE—What size of rope should be used and what horsepower will be required, to haul 6000 lbs. up a 45° incline at the rate of 600 ft. per minute?

SOLUTION—Starting at the upper left side of the diagram, at the line for 6000 lbs., trace horizontally to the right to the diagonal for 45° incline; thence vertically down to the center of the diagram, to find the rope size—⅝-in. diameter. Continuing vertically down to the diagonal for 600 ft. speed, and thence horizontally to the left side, the theoretical power required will be found—80 hp.

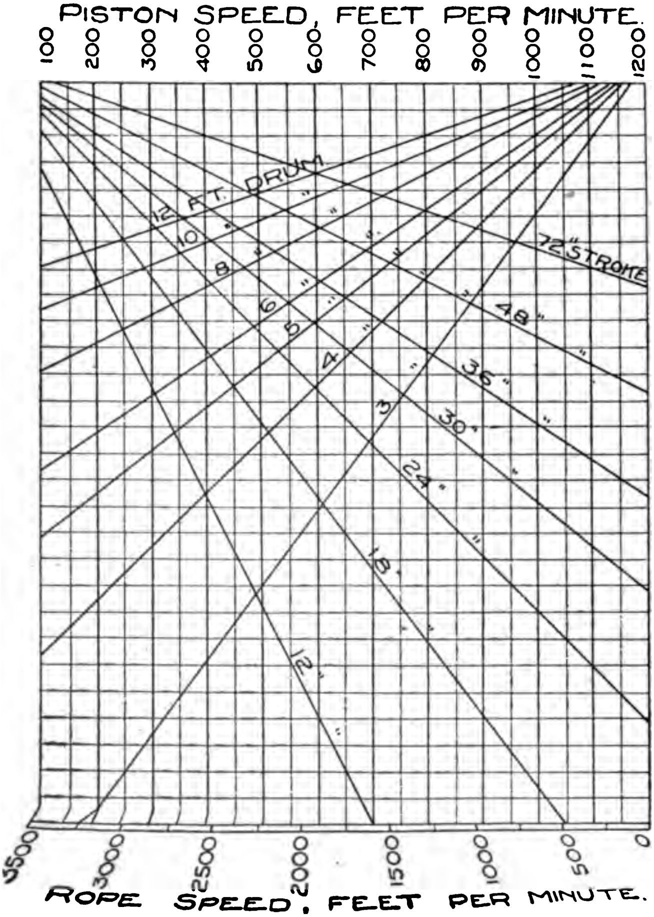
For the actual horsepower an additional allowance of about *25 percent must* be made, for friction, etc. Hence in the preser *example the actual* horsepower will be 80+20=100 hp.

Mine Hoisting—Continued

Diagram 1—Rope Speeds

Engine Speeds and Drum Diameters

See Instructions for Use, page 54

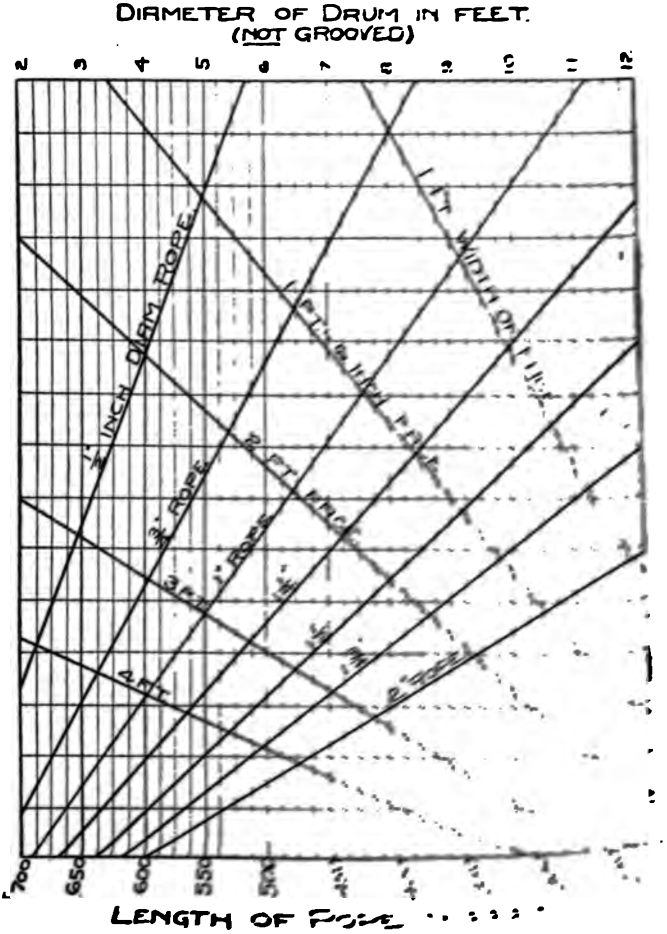


Mine Hoisting—Continued

Diagram 2—Drum Capacities

Single Layers of Rope

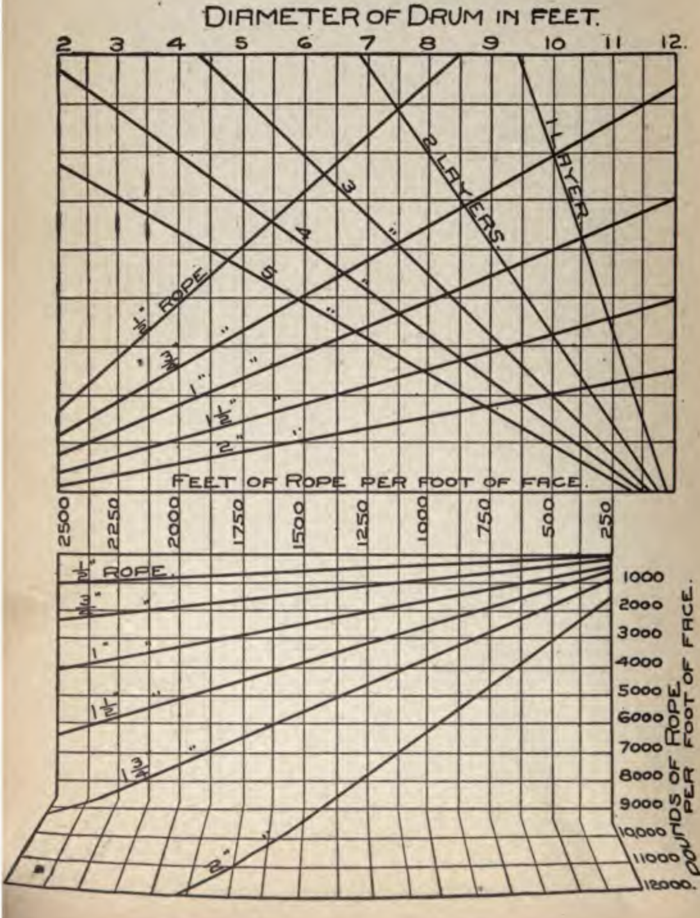
See Instructions for Use, page 54



Mine Hoisting—Continued

Diagram 3—Ropes in Multiple Layers
Lengths and Weights of Ropes in One or More Layers

See Instructions for Use, page 54

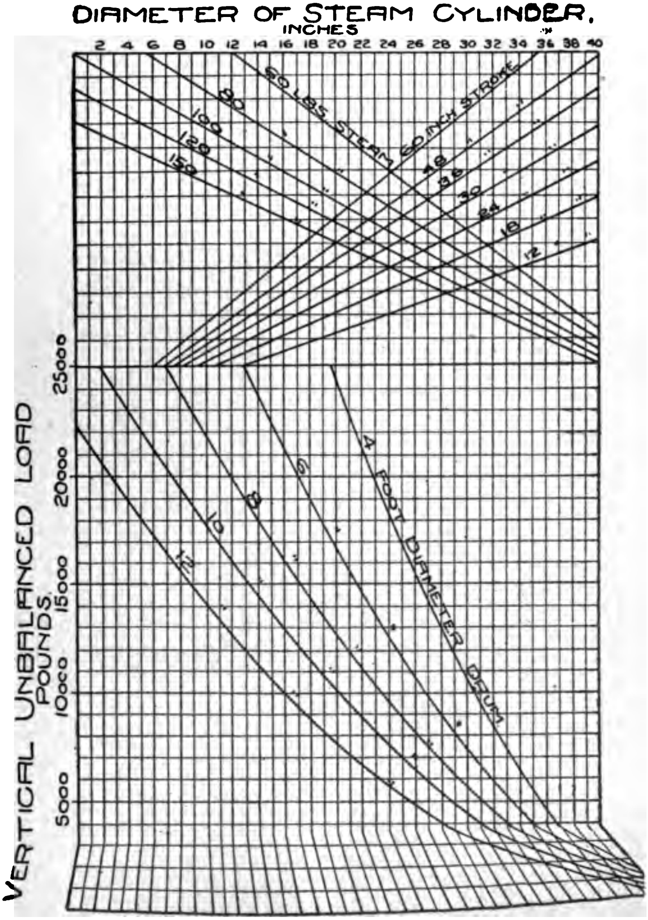


Mine Hoisting—Continued

Diagram 4—Load Capacities

Vertical Unbalanced Loads

See Instructions for Use, page 55

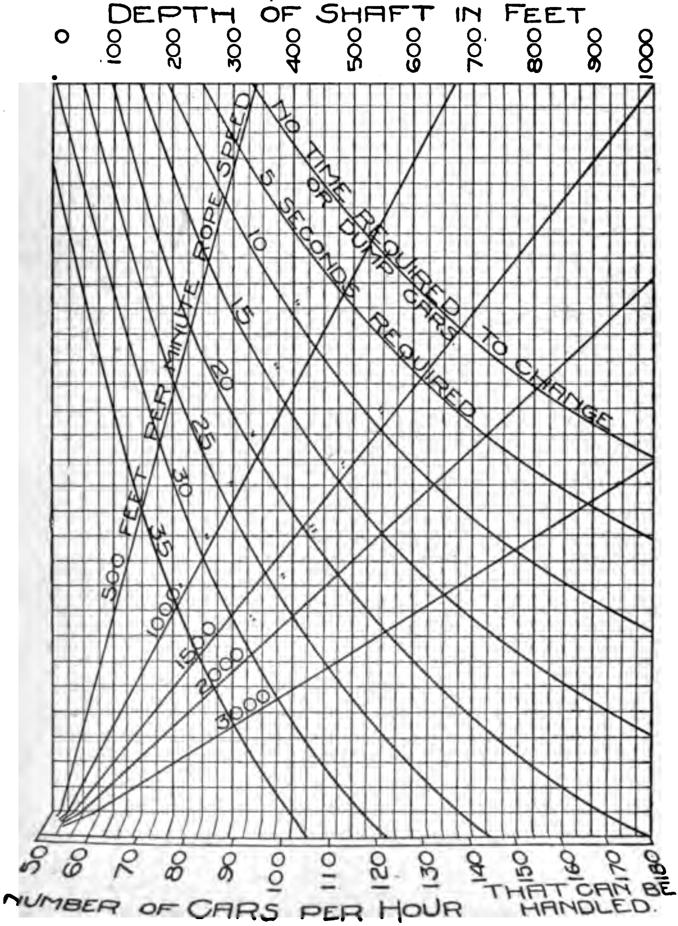


Mine Hoisting—Continued

Diagram 5—Rates of Hoisting

Cars Per Hour From Various Depths

See Instructions for Use, page 55

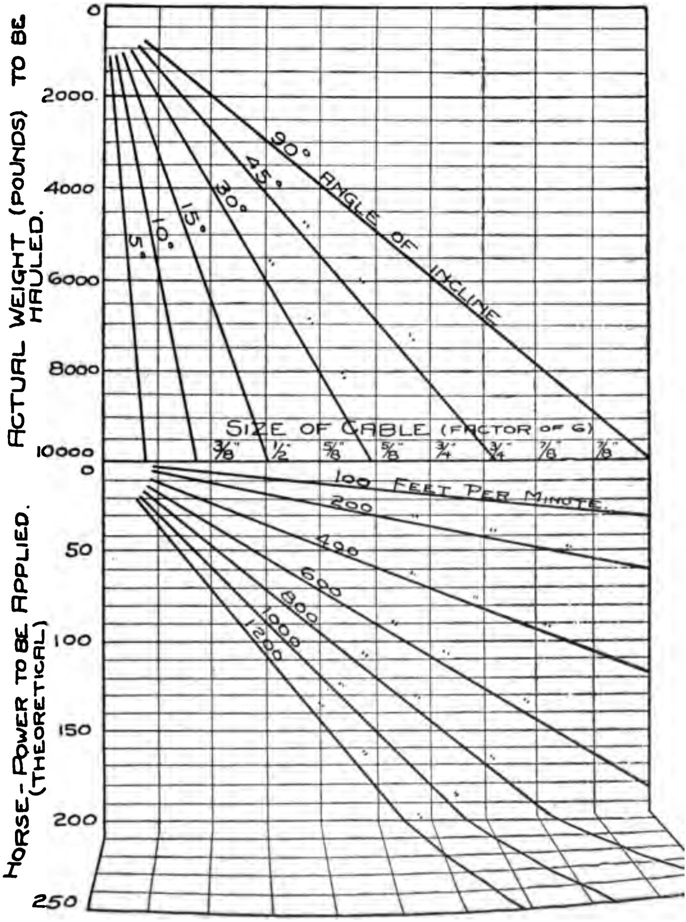


Mine Hoisting—Continued

Diagram 6—Hoisting on Inclines

Rope Sizes and Power Required

See Instructions for Use, page 55



Horsepower Required in Moving Air

Theoretical and Actual Powers for Various Rates of Flow, Under Different Pressures.

Efficiency of Fan taken at 65 to 70 percent.

Cubic Feet of Free Air per Minute	Pressure by Water Gauge—Inches: ½		¾		1		1¼		1½		2		2½	
	Horsepowers—Theoretical and Actual													
	Theo.	Actu.	Theo.	Actu.	Theo.	Actu.	Theo.	Actu.	Theo.	Actu.	Theo.	Actu.	Theo.	Actu.
15,000	1.1	1.6	1.7	2.5	2.3	3.5	2.9	4.1	3.5	5.2	4.7	7.1	5.9	8.9
20,000	1.5	2.5	2.3	3.3	3.1	4.6	3.9	5.7	4.7	7.0	6.2	9.4	7.8	11.9
25,000	2.0	2.8	3.0	4.3	4.0	5.8	4.9	7.3	6.0	8.8	8.0	12.1	10.0	15.1
30,000	2.2	3.2	3.4	5.0	4.6	7.0	5.8	8.2	7.0	10.4	9.4	14.2	11.8	17.8
40,000	3.3	4.7	4.7	6.7	6.3	9.0	7.8	11.5	9.5	14.0	12.6	19.5	15.7	23.7
50,000	3.9	5.5	5.9	8.4	7.9	11.6	9.8	14.4	11.8	17.4	15.7	23.8	19.6	29.7
60,000	4.7	6.7	7.1	10.1	9.5	14.0	11.8	16.4	14.2	20.8	18.8	28.5	23.6	35.7
70,000	5.5	7.8	8.2	11.6	11.0	16.2	13.7	20.2	16.5	24.5	22.0	33.0	27.5	41.0
80,000	6.3	9.0	9.4	13.4	12.6	18.5	15.7	23.1	19.0	28.0	25.0	37.9	31.5	47.7
90,000	7.1	10.1	10.3	15.2	14.2	20.5	17.4	25.6	21.2	31.2	28.0	42.5	35.5	53.0
100,000	8.0	11.4	12.0	17.2	16.0	23.5	20.0	29.5	24.0	35.3	32.0	48.5	40.0	60.7
125,000	10.0	14.3	15.0	21.4	20.0	29.4	25.0	36.8	30.0	44.1	40.0	60.7	49.0	74.2
150,000	12.0	17.1	18.0	25.7	24.0	35.3	30.0	44.1	36.0	53.0	47.0	71.1	59.0	89.2
200,000	16.0	22.9	24.0	34.3	32.0	47.0	40.0	58.8	47.0	68.0	63.0	95.2	79.0	120.0
250,000	19.5	27.9	29.3	42.0	39.0	57.2	48.8	71.8	59.0	86.8	79.0	120.0	98.0	148.2
300,000	23.5	33.7	35.2	50.0	47.0	69.0	58.7	86.2	71.0	104.0	94.0	142.2	118.0	178.5
350,000	27.5	39.3	41.2	59.0	55.0	80.8	68.7	100.5	83.0	120.0	110.0	167.0	138.0	209.0
400,000	31.5	45.0	47.3	67.5	63.0	92.8	78.8	113.0	95.0	140.0	126.0	191.0	157.0	238.0
450,000	35.5	50.9	53.0	75.1	71.0	104.0	88.5	130.0	106.0	156.0	141.0	214.0	175.0	265.0

Humidifying Mine Air

To Prevent Coal Dust Explosions

Investigations during the last few years, particularly by the U. S. Bureau of Mines, have brought out the rather surprising fact that, practically regardless of the relative humidity of the ventilating air at the intake, or of the temperature conditions, the relative humidity of the mine ventilating current when discharged from the mine varies from 80% to 100% and is usually over 90%.

The following table summarizes 48 tests that were made, and shows that for every 100,000 cubic feet of air circulated per minute, an average of 5,657 gallons of water is extracted from the mine by the ventilating current every 24 hours.

Extract from Bureau of Mines Bulletin, No. 20

State	Number of Mines	Number of Observations	Air Temperature, Degrees F.		Relative Humidity, Per Cent		Water Extracted, Gallons	
			Intake	Return	Intake	Return	Per 100,000 Cu. Ft.	Per 24 Hours
Alabama.....	5	5	71	69	72.5	92.5	2.27	3,269
Iowa.........	3	3	46.5	56.5	61.5	93	4.70	6,768
Illinois.......	8	11	45.5	58	60.5	91	4.44	6,394
New Mexico..	9	14	36	53	57	82	4.57	6,432
Colorado.....	1	1	72	70	18	85	9.02	12,991
West Virginia.	9	9	58.5	56	63	94	2.30	3,341
Virginia......	1	1	49	57	84	95.5	3.04	4,378
Pennsylvania.	1	4	48	49	87	91	1.17	1,685
Total....	39	48						
Average..			53	58.5	63	90.5	3.94	5,657

A review of analyses of American coals shows that the normal *moisture content* of green bituminous coal varies from 2% *to 15%.*

In tests made by the Bureau of Mines, coal dust has been exploded without the assistance of any gas, when the percentage of moisture was as high as 20%, but samples of dust which contain from 29% to 31% moisture could not be exploded. It would seem from these tests that if explosive coal dust is to be made safe by dampening or wetting, its moisture content should be increased from that of green bituminous coal, which normally varies from 2% to 15%, till it reaches at least 30%.

Since this is a known fact, and since coal dust is constantly being produced in the mine by blasting, shoveling, hauling, etc., various methods have been devised to keep the coal dust from being dangerous.

Following are some of the methods:

1. Loading and cleaning up such coal dust as can be reached, which is obviously a necessity. However, it is impossible to get at large quantities lodged on timbers and in crevices at remote points.

2. Sprinkling from water cars, or with a hose and nozzle, or with a permanent system of sprinklers. This, however, is only local in its effect, and will not reach the crevices, nor points which are remote from the tracks.

3. Application of calcium chloride or other deliquescent salt. This is also more or less local in its effect.

4. Coating the walls and floors of the passageways with rock dust, or placing such dust on easily overturned shelves, to confine the explosion within certain zones in the mine.

5. Adding moisture to the mine air. This is advisable if roof and other conditions permit, as it effectively reaches every part of the mine.

Air has the ability to hold a certain amount of invisible *moisture in suspension*. The higher the temperature of the *air, the greater is* the amount it will hold. When the air is *carrying all of the* invisible moisture it can, the condition is *known as saturation*.

The ratio of the amount of invisible moisture that is in the air at any temperature, to the maximum amount of invisible moisture it will carry when saturated at that temperature, expressed in percentage, is known as the relative humidity of the air. The Relative Humidity table on page 68 shows the amount of water the air will carry at any given temperature. Therefore, if the temperature of saturated air is lowered, a certain amount of the moisture that was invisible, becomes visible in the form of fog, vapor, or rain, and is deposited on any surface with which the air may come in contact.

In warm weather, when the relative humidity of the outside air is high and its temperature is lowered on entering the mine, the surplus moisture is deposited along the cooler walls of the mine, the process being known as sweating.

In cold weather, cool air enters the mine with a comparatively small percentage of moisture, but, warmed by the walls of the mine, the air develops a strong affinity for moisture, and abstracts it from the coal and other surfaces in the mine. It has been shown by the observations summarized in the foregoing table from the Bureau of Mines Bulletin that the air in this way will abstract enough moisture to reach a relative humidity of between 80% and 100% by the time it leaves the mine. This indicates the extreme power of cool mine air to dry up the dust.

Saturating the cold air at the intake does not remedy this evil, for as the air warms on encountering the warmer walls of the mine, its capacity for moisture increases, and it abstracts more from the surfaces with which it comes in contact.

Frequent saturation of the air along the passageways as it becomes warm will not render the explosive coal dust safe, because *saturating* such air at all parts of the mine simply *prevents it from* abstracting moisture from the coal dust and *does not cause it* to add moisture to the coal dust.

The only way, therefore, that the air current can deliver moisture to the coal dust when the air is cooler than the mine, is by being frequently moistened beyond the point of saturation, or "fogged" as it traverses the mine, so that the current carries in suspension in the form of steam, fog, or vapor a certain amount of moisture in addition to the invisible moisture required for saturation, this excess to be deposited upon the walls of the mine and on the dust. The moisture thus in suspension will be carried for long distances, because kept in floatation by the mechanical agitation of the air currents.

The exhaust steam from a fan is often used at the intake to accomplish this purpose, but the steam is injurious to many mine roofs and cannot always be used. Water sprayers, water jets operating under pressure, and driving water into the air in a finely divided state by centrifugal fans, are methods by which the super-saturated condition of the air is effected.

In order to be considered safe, the coal dust should be so damp that it sticks together when pressed in the hand. To be so damp as this, the dust must contain moisture to the extent of at least one-third its own weight.

The quantity of water that should be introduced into the air to nullify the tendency to dry out the mine can be calculated as follows:

Let A = Volume of air calculated, cu. ft. per minute.

T = Temperature of intake air, degrees Fahr.

t = Temperature of outlet air, degrees Fahr.

H = Relative humidity of intake air, per cent.

h = Relative humidity of outlet air, per cent (nearly always *close to 90%).*

I = Quantity of water in intake air, gallons per 100,000 *cu. ft.*

Let R = Quantity of water in return air, gallons per 100,000 cu. ft.

W = Quantity of water to be added to neutralize drying tendency of Volume A of air as it warms in passing through the mine, gallons per minute.

Then I is given by table on page 69, for temperature T and relative humidity H.

R is given by table on page 69, for temperature t and relative humidity h.

And W = $(R-I)\times(A\div 100{,}000)$
= theoretical quantity of water to be added. Actually this must be increased by at least 20% to allow for failure of the air to take up all the moisture from the sprayers or jets.

EXAMPLE—What quantity of water must be added to neutralize the drying tendency of an air current of 85,000 cu. ft. per minute, entering the mine with a temperature of 45° F. and a relative humidity of 70%, and leaving with a temperature averaging 60° F. and the usual relative humidity of 90%?

SOLUTION—The conditions give: $A=85{,}000$, $T=45$, $t=60$, $H=70$ and $h=90$. The table on page 61 gives $I=4.092$ for T and H, and $R=8.859$ for t and h.

Then $W=(8.859-4.092)\times(85{,}000\div 100{,}000)$
$=4.767\times 0.85$
$=4.05195$ or 4.05 nearly.

This theoretical must be increased 20% for the actual quantity of water to be added, which gives $4.05\times 1.20=4.86$ gallons per minute, actual.

Then $4.86\times 60=291.6$, or 292 nearly, is the quantity of water in gallons per hour.

The extra quantity required to super-saturate the air so as to add the desired moisture to the coal dust must be determined by trial.

The power required to circulate the ventilating air can be *estimated by the* use of the table on page 62.

Relative Humidity

Percentages of Complete Saturation

By differences between Readings of Wet and Dry Bulb Thermometers.

Difference Between Wet and Dry Thermometers	Temperature, Degrees Fahrenheit							
	32	40	50	60	70	80	90	100
	Relative Humidity, Per Cent (Barometer, 30 Inches)							
1	89	92	93	94	95	96	96	96
2	79	83	87	89	90	91	92	93
3	69	75	80	83	86	87	89	89
4	59	68	74	78	81	83	85	86
5	49	60	67	73	77	79	81	83
6	39	52	61	68	72	75	78	80
7	30	45	55	63	68	72	74	77
8	20	37	49	58	64	68	71	73
9	11	29	43	53	59	64	68	70
10	2	23	38	48	55	61	65	68
11	......	15	32	43	51	57	61	65
12	......	7	27	39	48	54	58	62
13	......	0	21	34	44	50	55	59
14	......	......	16	30	40	47	52	56
15	......	......	11	26	36	44	49	54
16	......	......	5	21	33	41	47	51
17	......	......	0	17	29	38	44	49
18	......	......	......	13	25	35	41	46
19	......	......	......	9	22	32	39	44
20	......	......	......	5	19	29	36	41
21	......	......	......	1	15	26	34	39
22	......	......	......	......	12	23	31	37
23	......	......	......	......	9	20	29	35
24	......	......	......	......	6	18	26	33
26	......	......	......	......	......	12	22	28
28	......	......	......	......	......	7	17	24
30	......	......	......	......	......	......	13	21

Water in Moist Air

Gallons per 100,000 Cubic Feet of Air, at Various Temperatures and Percentages of Saturation

Temperature, Degrees Fahr.	Relative Humidity, Per cent								
	20	30	40	50	60	70	80	90	100
	Gallons of Water Per 100,000 Cu. Ft. of Air								
–20	.057	.085	.114	.142	.170	.199	.227	.256	.284
–15	.075	.112	.149	.187	.224	.261	.298	.336	.373
–10	.098	.146	.195	.244	.293	.342	.390	.439	.488
–5	.127	.190	.253	.317	.380	.443	.506	.570	.633
0	.165	.247	.329	.412	.494	.576	.658	.741	.823
5	.209	.313	.418	.522	.626	.731	.835	.940	1.044
10	.266	.399	.532	.665	.797	.930	1.063	1.196	1.329
15	.338	.506	.675	.844	1.013	1.182	1.350	1.519	1.688
20	.423	.634	.846	1.057	1.268	1.480	1.691	1.903	2.114
25	.531	.797	1.062	1.328	1.593	1.859	2.124	2.390	2.655
30	.662	.994	1.325	1.656	1.987	2.318	2.650	2.981	3.312
35	.810	1.215	1.620	2.026	2.431	2.836	3.241	3.646	4.051
40	.976	1.463	1.951	2.439	2.927	3.415	3.902	4.390	4.878
45	1.169	1.754	1.338	2.923	3.507	4.092	4.676	5.261	5.845
50	1.396	2.094	2.792	3.490	4.187	4.885	5.583	6.281	6.979
55	1.661	2.493	3.322	4.153	4.984	5.814	6.645	7.475	8.306
60	1.969	2.953	3.937	4.922	5.906	6.890	7.874	8.859	9.843
65	2.325	3.488	4.650	5.813	6.976	8.138	9.301	10.46	11.63
70	2.737	4.106	5.474	6.843	8.212	9.580	10.95	12.32	13.69
75	3.211	4.816	6.422	8.027	9.632	11.24	12.84	14.45	16.05
80	3.755	5.633	7.510	9.388	11.27	13.14	15.02	16.90	18.78
85	4.378	6.566	8.755	10.94	13.13	15.32	17.51	19.70	21.89
90	5.088	7.632	10.18	12.72	15.26	17.81	20.35	22.90	25.44
95	*5.895*	*8.843*	11.79	14.74	17.69	20.63	23.58	26.53	29.48
100	*6.812*	*10.22*	13.62	17.03	20.44	23.84	27.25	30.65	34.06

Compressed Air Pressures

Initial pressures required for delivery of air at 80 pounds gauge pressure through 1000 feet of clean and straight pipe, at various velocities.

Velocity of Flow, Feet per Second	1-in. Pipe		1½-in. Pipe		2-in. Pipe	
	Cu. Ft. Free Air per Min.	Initial Pressure Required	Cu. Ft. Free Air per Min.	Initial Pressure Required	Cu. Ft. Free Air per Min.	Initial Pressure Required
3.07	6	80.337	14	80.134	23	80.100
6.14	12	81.348	29	80.536	47	80.400
9.20	18	83.033	43	81.206	70	80.900
12.27	24	85.392	57	82.144	94	81.600
15.34	30	88.425	72	83.350	118	82.500
18.41	36	92.132	86	84.824	141	83.600
24.54	48	101.568	115	88.576	188	87.200
30.68	60	113.700	144	93.400	235	90.000
	2½-in. Pipe		3-in. Pipe		4-in. Pipe	
3.07	33	80.058	52	80.050	88	80.031
6.14	67	80.232	104	80.200	176	80.124
9.20	100	80.522	156	80.450	264	80.279
12.27	134	80.928	208	80.800	352	80.495
15.34	168	81.450	260	81.250	440	80.775
18.41	201	82.088	312	81.800	528	81.116
24.54	268	83.712	416	83.200	704	81.984
30.68	335	85.800	520	85.000	880	83.100
	5-in. Pipe		6-in. Pipe		8-in. Pipe	
3.07	141	80.022	204	80.018	353	80.011
6.14	282	80.088	408	80.072	706	80.044
9.20	423	80.198	612	80.162	1059	80.099
12.27	564	80.352	816	80.288	1412	80 176
15.34	705	80.550	1020	80.450	1765	80.275
18.41	846	80.792	1224	80.648	2118	80.336
24.54	1128	81.408	1632	81.152	2824	80.704
30.68	1410	82.200	2040	81.800	3530	81.100
	10-in. Pipe		12-in. Pipe		14-in. Pipe	
3.07	566	80.009	799	80.007	1087	80.006
6.14	1132	80.035	1598	80.027	2174	80.022
9.20	1698	80.078	2397	80.060	3261	80.050
12.37	2264	80.139	3196	80.107	4348	80.088
15.34	2830	80.218	3995	80.168	5435	80.138
18.41	3396	80.313	4794	80.241	6522	80.198
24.54	4528	80.557	6392	80.429	8696	80.352
30 68	5660	80.870	7990	80.670	10870	80.550

Properties of Saturated Steam

(Marks and Davis)

Pressure by Gauge, Lbs. per Sq. In.	Temperature of Steam, Degrees, Fahr.	Total Heat of Steam in B. T. U. above Water at 32° Fahr.	Weight of Steam, Pounds per Cubic Foot	Volume, Cu. Ft. per Pound of Steam
0	212.0	1150.4	.0373	26.79
5.3	228.0	1156.2	.0498	20.08
15.3	250.3	1163.9	.0728	13.74
25.3	267.3	1169.4	.0953	10.49
35.3	281.0	1173.6	.1175	8.51
45.3	292.7	1177.0	.1395	7.17
55.3	302.9	1179.8	.1612	6.20
65.3	312.0	1182.3	.1829	5.47
75.3	320.3	1184.4	.2044	4.89
85.3	327.8	1186.3	.2258	4.429
95.3	335.5	1188.0	.2472	4.047
105.3	341.3	1189.6	.2683	3.726
115.3	347.4	1191.0	.2897	3.452
125.3	353.1	1192.2	.3107	3.219
135.3	358.5	1193.4	.3320	3.012
145.3	363.6	1194.5	.3529	2.834
155.3	340.7	1195.4	.3738	2.675
165.3	345.6	1196.4	.3948	2.533
175.3	350.4	1197.3	.4157	2.406
205.3	363.4	1199.6	.478	2.091
225.3	397.4	1200.9	.520	1.924
255.3	407.9	1202.6	.582	1.718
275.3	414.4	1203.6	.624	1.602
305.3	423.4	1204.9	.687	1.456
325.3	431.9	1206.1	.750	1.372
355.3	437.2	1206.8	.791	1.264
385.3	444.8	1208.0	.860	1.170
435.3	456.5	1209.0	.960	1.140
485.3	467.3	1210.0	1.080	.93

Standard Wrought Pipe

Standard Dimensions and List Prices

Diameter, Inches			Number of Threads per Inch	Length of Perfect Thread, Inches	Weight, Pounds per Lineal Foot	List Price per Foot
Nominal Inside	Actual					
	Outside	Inside				
1/8	.405	.269	27	.19	.24	$0.05½
¼	.540	.364	18	.29	.42	.06
⅜	.675	.493	18	.30	.57	.06
½	.840	.622	14	.39	.85	.08½
¾	1.050	.824	14	.40	1.13	.11½
1	1.315	1.049	11½	.51	1.68	.17
1¼	1.660	1.380	11½	.54	2.27	.23
1½	1.900	1.610	11½	.55	2.71	.27½
2	2.375	2.067	11½	.58	3.65	.37
2½	2.875	2.469	8	.89	5.79	.58½
3	3.500	3.068	8	.95	7.57	.76½
3½	4.000	3.548	8	1.00	9.11	.92
4	4.500	4.026	8	1.05	10.79	1.09
4½	5.000	4.506	8	1.10	12.54	1.27
5	5.563	5.047	8	1.16	14.61	1.48
6	6.625	6.065	8	1.26	18.97	1.92
7	7.625	7.023	8	1.36	23.54	2.38
8	8.625	7.981	8	1.46	28.55	2.88
9	9.625	8.941	8	1.57	33.91	3.45
10	10.750	10.020	8	1.68	40.48	4.12
11	11.750	11.000	8	1.78	45.56	4.63
12	*12.750*	12.000	8	1.88	49.56	5.07
13	*14.000*	13.250	8	2.09	54.57	5.60
14	*15.000*	14.250	8	2.10	58.57	6.10
15	*16.000*	15.250	8	2.20	62.58	6.50

Extra Strong Wrought Pipe

Standard Dimensions and List Prices

Diameter, Inches			Internal Area, Square Inches	Length Containing one Cubic Foot, Feet	Weight, Pounds per Lineal Foot	List Price per Foot
Nominal Inside	Actual					
	Outside	Inside				
⅛	.405	.215	.036	3966.39	.314	$0.12
¼	.540	.302	.072	2010.29	.535	.07½
⅜	.675	.423	.141	1024.69	.738	.07½
½	.840	.546	.234	615.02	1.087	.11
¾	1.050	.742	.433	333.02	1.473	.15
1	1.315	.957	.719	200.19	2.171	.22
1¼	1.660	1.278	1.283	112.26	2.996	.30
1½	1.900	1.500	1.767	81.49	3.631	.36½
2	2.375	1.939	2.953	48.77	5.022	.50½
2½	2.875	2.323	4.238	33.98	7.661	.77
3	3.500	2.900	6.605	21.80	10.252	1.03
3½	4.000	3.364	8.888	16.20	12.505	1.25
4	4.500	3.826	11.497	12.53	14.983	1.50
4½	5.000	4.290	14.455	9.96	17.611	1.80
5	5.563	4.813	18.194	7.92	20.778	2.08
6	6.625	5.761	26.067	5.52	28.573	2.86
7	7.625	6.625	34.472	4.18	38.048	3.81
8	8.625	7.625	45.663	3.15	43.388	4.34
9	9.625	8.625	58.426	2.46	48.728	4.90
10	10.750	9.750	74.662	1.93	54.735	5.48
11	11.750	10.750	90.763	1.59	60.075	6.10
12	12.750	11.750	108.434	1.33	65.415	6.55

Double Extra Strong Wrought Pipe

Standard Dimensions and List Prices

Diameter, Inches			Internal Area, Square Inches	Length Containing one Cubic Foot, Feet	Weight, Pounds per Lineal Foot	List Price per Foot
Nominal Inside	Actual Outside	Actual Inside				
½	.840	.252	.050	2887.16	1.714	$0.32
¾	1.050	.434	.148	973.40	2.440	.35
1	1.315	.599	.282	511.00	3.659	.37
1¼	1.660	.896	.630	228.38	5.214	.52½
1½	1.900	1.100	.950	151.53	6.408	.65
2	2.375	1.503	1.774	81.16	9.029	.91
2½	2.875	1.771	2.464	58.46	13.695	1.37
3	3.500	2.300	4.155	34.66	18.583	1.86
3½	4.000	2.728	5.845	24.64	22.850	2.30
4	4.500	3.152	7.803	18.45	27.541	2.76
4½	5.000	3.580	10.066	14.31	32.530	3.26
5	5.563	4.063	12.966	11.11	38.552	3.86
6	6.625	4.897	18.835	7.65	53.160	5.32
7	7.625	5.875	27.109	5.31	63.079	6.35
8	8.625	6.875	37.122	3.88	72.424	7.25

Round Cisterns, Tanks, Pipes, Etc.

Areas and Capacities in U. S. Gallons per Foot of Depth for Various Diameters

Diam., Inches	Area, Sq. Ft.	Gallons per Ft. Depth	Diam., Ft.—In.	Area, Sq. Ft.	Gallons per Ft. Depth	Diam., Ft.—In.	Area, Sq. Ft.	Gallons per Ft. Depth
1/4	.0003	.0025	1–2	1.069	8.00	11–0	95.0	711
3/8	.0008	.0057	1–4	1.396	10.44	11–6	103.9	777
			1–6	1.767	13.22			
1/2	.0014	.0102	1–8	2.182	16.32	12–0	113.1	846
5/8	.0021	.0159	1–10	2.640	19.75	12–6	122.7	918
3/4	.0031	.0230				13–0	132.7	993
7/8	.0042	.0312	2–0	3.142	23.50	13–6	143.1	1071
			2–2	3.687	27.58			
1	.0055	.0408	2–4	4.276	31.99	14–0	153.9	1152
1 1/4	.0085	.0638	2–6	4.909	36.72	14–6	165.1	1235
1 1/2	.0123	.0918	2–8	5.585	41.78	15–0	176.7	1322
1 3/4	.0167	.1249	2–10	6.305	47.16	15–6	188.7	1412
2	.0218	.1632	3–0	7.069	52.88	16–0	201.1	1504
2 1/4	.0276	.2066	3–3	8.296	62.06	16–6	213.8	1600
2 1/2	.0341	.2550	3–6	9.620	71.97	17–0	227.0	1698
2 3/4	.0412	.3085	3–9	11.045	82.62	17–6	240.5	1799
3	.0491	.3672	4–0	12.566	94.00	18–0	254.5	1904
3 1/2	.0668	.4998	4–6	15.90	118.97	18–6	268.8	2011
4	.0873	.6528	5–0	19.63	146.88	19–0	283.5	2121
4 1/2	.1104	.8263	5–6	23.76	177.72	19–6	298.7	2234
5	.1364	1.020	6–0	28.27	211.51	20–0	314.2	2350
5 1/2	.1650	1.234	6–6	33.18	248.23	20–6	330.1	2469
6	.1963	1.469	7–0	38.48	287.88	21–0	346.4	2591
6 1/2	.2304	1.724	7–6	44.18	330.48	21–6	363.1	2716
7	.2673	1.999	8–0	50.27	376.01	22–0	380.1	2844
7 1/2	.3068	2.295	8–6	56.75	424.48	22–6	397.6	2974
8	.3491	2.611	9–0	63.62	475.89	23–0	415.5	3108
9	.4418	3.305	9–6	70.88	530.24	23–6	433.7	3245
10	.5454	4.080	10–0	78.54	587.52	24–0	452.4	3384
11	.6669	4.937	10–6	86.59	647.74	24–6	471.4	3527
12	.7854	5.875				25–0	490.9	3672

1 gallon = *231* cu. in. = .13368 cu. ft. = 8.32 lbs. water approximately.

1 cu. ft. = *62 1/4* lbs. water approximately.

1 barrel = *31 1/2* gallons.

Comparative Table

Number of Smaller Pipes

With the same velocity of flow, the volume delivered by two pipes of different sizes is proportional to the squares of their diameters. With the same head or pressure, however, the velocity is less in the smaller pipe and the volume delivered varies about

Large Pipe, Diam., Ins.	Smaller Pipes, Diameters, Inches						
	1	2	3	4	5	6	7
	Number to Give Same Capacity as One Large Pipe						
2	5.7	....	....	....	....	....	....
3	15.6	2.8	....	....	....	....	....
4	32.0	5.7	2.1	....	....	....	....
5	55.9	9.9	3.6	1.7	....	....	....
6	88.2	15.6	5.7	2.8	1.6	....	....
7	130	22.9	8.3	4.1	2.3	1.5	....
8	181	32.0	11.7	5.7	3.2	2.1	1.4
9	243	43.0	15.6	7.6	4.3	2.8	1.9
10	316	55.9	20.3	9.9	5.7	3.6	2.4
11	401	70.9	25.7	12.5	7.2	4.6	3.1
12	499	88.2	32.0	15.6	8.9	5.7	3.8
13	609	108	39.1	19.0	10.9	7.1	4.7
14	733	130	47.0	22.9	13.1	8.3	5.7
15	871	154	55.9	27.2	15.6	9.9	6.7
16	....	181	65.7	32.0	18.3	11.7	7.9
17	....	211	76.4	37.2	21.3	13.5	9.2
18	....	243	82.2	43.0	24.6	15.6	10.6
20	....	316	115	55.9	32.0	20.3	13.8
22	....	401	146	70.9	40.6	25.7	17.5
24	....	499	181	88.2	50.5	32.0	21.8

# of Pipe Capacities

Equivalent to One Larger

as the square root of the 5th power. The table is calculated on this basis, the figures in each column showing the number of pipes of the size at the head of that column, equivalent in capacity to one pipe of the corresponding sizes given in side columns.

Smaller Pipes, Diameters, Inches								Large Pipe, Diam., Ins.
8	9	10	12	14	16	18	20	
Number to Give Same Capacity as One Large Pipe								
......	......	......	......	......	......	......	......	2
......	......	......	......	......	......	......	......	3
......	......	......	......	......	......	......	......	4
......	......	......	......	......	......	......	......	5
......	......	......	......	......	......	......	......	6
......	......	......	......	......	......	......	......	7
......	......	......	......	......	......	......	......	8
1.3	......	......	......	......	......	......	......	9
1.7	1.3	......	......	......	......	......	......	10
2.2	1.7	1.3	......	......	......	......	......	11
2.8	2.1	1.6	......	......	......	......	......	12
3.4	2.5	1.9	1.2	......	......	......	......	13
4.1	3.0	2.3	1.5	......	......	......	......	14
4.8	3.6	2.8	1.7	1.2	......	......	......	15
5.7	4.2	3.2	2.1	1.4	......	......	......	16
6.6	4.9	3.8	2.4	1.6	1.2	......	......	17
7.6	5.7	4.3	2.8	1.9	1.3	......	......	18
9.9	7.4	5.7	3.6	2.4	1.7	1.3	......	20
12.5	9.3	7.2	4.6	3.1	2.2	1.7	1.3	22
15.6	11.6	8.9	5.7	3.8	2.8	2.1	1.6	24

Weir Measurement of Water

When the depth of water flowing over a sill or a weir notch is known, the quantity of water passing can be calculated from the table below. The method of using the table is illustrated by the following example:

A weir notch is 16 inches wide; the height of the water some distance back of the notch at a point where the water is level, is observed to be 7⅜ inches above the bottom of the notch or weir sill. How many cubic feet of water per minute are flowing through this notch?

The table shows that for a height of 7⅜ inches over the sill, water flows at the rate of 8.01 cubic feet per minute per inch of width. Since this notch is 16 inches wide, the flow is at the rate of 16×8.01 = 128.16 cubic feet per minute.

Weir Table

Level Depth over Weir, Inches	Flow of Water, Cu. Ft. per Minute per Inch of Width							
	Even Inches Depth	Additional Fractions of an Inch Depth						
		⅛	¼	⅜	½	⅝	¾	⅞
0	.00	.01	.05	.09	.14	.19	.26	.32
1	.40	.47	.55	.64	.73	.82	.92	1.02
2	1.13	1.23	1.35	1.46	1.58	1.70	1.82	1.95
3	2.07	2.21	2.34	2.48	2.61	2.76	2.90	3.05
4	3.20	3.35	3.50	3.66	3.81	3.97	4.14	4.30
5	4.47	4.64	4.81	4.98	5.15	5.33	5.51	5.69
6	5.87	6.06	6.25	6.44	6.62	6.82	7.01	7.21
7	7.40	7.60	7.80	8.01	8.21	8.42	8.63	8.83
8	9.05	9.26	9.47	9.69	9.91	10.13	10.35	10.57
9	10.80	11.02	11.25	11.48	11.71	11.94	12.17	12.41
10	12.64	12.88	13.12	13.36	13.60	13.85	14.09	14.34
11	14.59	14.84	15.09	15.34	15.59	15.85	16.11	16.36
12	16.62	16.88	17.15	17.41	17.67	17.94	18.21	18.47
13	18.74	19.01	19.29	19.56	19.84	20.11	20.39	20.67
14	20.95	21.23	21.51	21.80	22.08	22.37	22.65	22.94
15	23.23	23.52	23.82	24.11	24.40	24.70	25.00	25.30
16	25.60	25.90	26.20	26.50	26.80	27.11	27.42	27.72
17	28.03	28.34	28.65	28.97	29.28	29.59	29.91	30.22
18	30.54	30.86	31.18	31.50	31.82	32.15	32.47	32.80
19	33.12	33.45	33.78	34.11	34.44	34.77	35.10	35.44
20	35.77	36.11	36.45	36.78	37.12	37.46	37.80	38.15

Pounds Pressure—Feet Head Of Water

Equivalents of pounds pressure per square inch in feet head of water, and vice versa.

Pounds per Sq. In.	Feet Head	Pounds per Sq. In.	Feet Head	Feet Head	Pounds per Sq. In.	Feet Head	Pounds per Sq. In.
1	2.31	110	253.9	1	.43	140	60.63
2	4.62	120	277.1	2	.87	150	64.96
3	6.93	130	300.2	3	1.30	160	69.29
4	9.24	140	323.3	4	1.73	170	73.63
5	11.54	150	346.3	5	2.17	180	77.96
6	13.85	160	369.4	6	2.60	190	82.29
7	16.16	170	392.5	7	3.03	200	86.62
8	18.47	180	415.6	8	3.40	225	97.45
9	20.78	190	438.9	9	3.90	250	108.3
10	23.09	200	461.8	10	4.33	275	119.1
12	27.6	225	519.5	15	6.50	300	129.9
14	32.2	250	577.2	20	8.66	325	140.8
16	36.8	275	643.0	25	10.83	350	151.6
18	41.4	300	692.7	30	12.99	375	162.4
20	46.2	325	750.4	35	15.16	400	173.2
25	57.7	350	808.1	40	17.32	425	184.0
30	69.3	375	865.9	45	19.49	450	194.8
35	80.8	400	922.6	50	21.65	475	205.7
40	92.4	425	980.3	55	23.82	500	216.5
45	103.9	450	1038	60	25.99	550	238.2
50	115.5	475	1096	65	28.15	600	259.8
55	126.9	500	1155	70	30.32	650	281.4
60	138.5	550	1269	75	32.48	700	303.2
65	150.1	600	1385	80	34.65	750	324.8
70	161.6	650	1501	85	36.81	800	346.5
75	173.2	700	1616	90	38.98	850	368.1
80	184.7	750	1732	95	41.14	900	389.8
85	196.3	800	1847	100	43.31	950	411.4
90	207.8	850	1963	110	47.64	1000	433.1
95	219.4	900	2078	120	51.97	1100	476.4
100	230.9	1000	2309	130	56.30	1200	519.7

Water Pressure Losses by Friction in Iron and Steel Pipes

Friction losses in pounds pressure per square inch for each 100 feet of clean and straight iron pipe at various rates of flow.

Flow, Gallons per Min.	Pipe Size, Inches								
	1	1½	2	2½	3	4	6	8	10
	Pressure Loss in Pounds per Sq. In. per 100 Ft. of Pipe.								
10	3.16	0.47	0.12	......	......	......	.....	.....	.....
20	12.3	1.66	0.42	......	......	......	.....	.....	.....
30	27.5	3.75	0.91	0.40	......	......	.....	.....	.....
40	48.0	6.52	1.60	0.57	0.27	......	.....	.....	.....
50	......	10.0	2.44	0.81	0.35	0.09	.....	.....	.....
75	......	22.4	5.32	1.80	0.74	0.20	.....	.....	.....
100	......	39.0	9.46	3.20	1.31	0.33	0.05	0.03	.....
150	......	......	21.20	7.00	2.35	0.69	0.10	0.04	.....
200	......	......	37.50	12.47	5.02	1.22	0.17	0.05	0.02
250	......	......	......	19.66	7.76	1.89	0.26	0.07	0.03
300	......	......	......	28.06	11.2	2.66	0.37	0.09	0.04
400	......	......	......	......	19.5	4.73	0.65	0.16	0.06
500	......	......	......	......	30.8	7.43	0.96	0.25	0.09
750	......	......	......	......	......	......	2.21	0.53	0.18
1000	......	......	......	......	......	......	3.88	0.94	0.32
1250	......	......	......	......	......	......	.....	1.46	0.49
1500	......	......	......	......	......	......	.....	2.09	0.70
1750	......	......	......	......	......	......	.....	.....	0.95
2000	......	......	......	......	......	......	.....	.....	1.23

Water Pressure Losses by Friction in Wood Pipes

Head in Feet of Water Lost per 1,000 Feet of Pipe at Various Rates of Flow

Rate of Flow, Feet per Second	Pipe Size, Inches						
	4	6	8	12	16	20	30
	Head in Feet Lost per 1,000 Feet						
1	.97	.63	.43	.26	.18	.11	.09
1.5	2.3	1.3	.97	.61	.41	.22	.16
2	4.2	2.4	1.6	1.1	.73	.45	.29
2.5	6.5	3.8	2.6	1.7	1.2	.83	.47
3	9.4	5.5	3.9	2.5	1.6	1.1	.66
3.5	12.6	7.4	5.5	3.4	2.3	1.6	.89
4	16.0	9.5	7.2	4.4	3.0	2.1	1.1
4.5	19.7	12.1	9.2	5.5	3.8	2.7	1.4
5	23.6	15.1	11.3	6.7	4.7	3.3	1.8
5.5	27.5	18.1	13.5	8.1	5.6	4.0	2.2
6	......	21.4	16.0	9.7	6.7	4.8	2.7
6.5	......	25.1	18.7	11.5	7.7	5.6	3.2
7	......	......	21.5	13.3	8.8	6.5	3.7
7.5	......	......	24.4	15.3	10.2	7.3	4.2
8	......	......	27.3	17.2	11.6	8.3	4.7
8.5	......	......	......	19.3	13.1	9.3	5.2
9	......	......	......	21.5	14.6	10.2	5.7
9.5	......	......	......	22.8	16.1	11.2	6.3
10	......	......	......	......	17.6	12.2	6.8

Water Pressure Losses by Friction in Elbows

Friction losses in pounds pressure per square inch for each elbow, at various rates of flow.

Flow, Gallons per Minute	Pipe Size, Inches — Pressure Loss in Pounds per Sq. In. per Elbow								
	1	1½	2	2½	3	4	6	8	10
10	.094	.018	.006	.003	.....	.....	.....	.....	.....
20	.376	.069	.025	.012	.005	.....	.....	.....	.....
30	.845	.157	.055	.028	.011	.....	.....	.....	.....
40	1.50	.278	.098	.049	.02	.007	.....	.....	.....
50	2.58	.43	.153	.08	.032	.01	.....	.....	.....
75	5.30	.98	.35	.172	.072	.024	.005	.....	.....
100	.....	1.72	.612	.32	.128	.043	.008	.003	.....
150	.....	3.92	1.39	.685	.286	.096	.019	.006	.003
200	.....	6.88	2.44	1.28	.512	.172	.032	.011	.005
250	.....	.....	3.86	1.91	.80	.268	.052	.017	.007
300	.....	.....	5.56	2.74	1.14	.384	.076	.025	.01
350	.....	.....	.....	3.77	1.38	.530	.103	.034	.014
400	.....	.....	.....	5.12	2.05	.688	.128	.044	.018
450	.....	.....	.....	6.20	2.58	.870	.170	.057	.023
500	.....	.....	.....	7.64	3.20	1.07	.208	.068	.028
750	.....	.....	.....	.....	.....	2.42	.470	.156	.063
1000	.....	.....	.....	.....	.....	4.28	.832	.272	.112
1250	.....	.....	.....	.....	.....	6.70	1.31	.435	.175
1500	.....	.....	.....	.....	.....	9.68	1.88	.624	.252

To find the friction head in feet of water, multiply the above *gures by 2.3 or see* table on next page.

Capacities of Pumps

Plunger Displacements per Stroke, in Gallons

For approximate capacity of any pump per minute, multiply capacity per plunger per stroke from table below, by number of working strokes per minute for all plungers.

When pump is new and in good condition, deduct 10% to allow for slip, rod displacements, etc. When pump is in poor condition and piping is old, greater allowances must be made.

Plunger Size		Length of Stroke, Inches						
Diam., In.	Area, Sq. In.	3	4	6	8	10	12	16
		Theoretical Capacity per Plunger Stroke, Gallons						
1½	1.77	0.023	0.031	0.046	......	......	......	......
2	3.14	.041	.054	.082	0.109	......	......	......
2½	4.91	.064	.085	.128	.170	0.213	......	......
3	7.07	.092	.122	.184	.245	.306	0.367	......
3½	9.62	.125	.167	.250	.333	.417	.500	......
4	12.57	.163	.218	.326	.435	.544	.653	0.870
4½	15.90	.207	.275	.413	.551	.689	.826	1.102
5	19.64	.255	.340	.510	.680	.850	1.020	1.360
5½	23.76	.309	.411	.617	.823	1.020	1.234	1.646
6	28.27	.367	.490	.734	.979	1.224	1.469	1.958
7	38.49	......	.666	1.000	1.333	1.666	1.999	2.666
8	50.27	......	.870	1.306	1.741	2.176	2.611	3.482
9	63.62	......	......	1.652	2.203	2.754	3.305	4.406
10	78.54	......	......	2.040	2.720	3.400	4.080	5.440
12	113.1	......	......	2.938	3.917	4.896	5.875	7.833
14	153.9	......	......	......	5.330	6.663	7.994	10.66
16	201.1	......	......	......	6.960	8.703	10.44	13.92
20	314.2	......	......	......	......	13.60	16.32	21.76

Theoretical Horsepower Required in Raising Water

Using Motor-Driven Pump.

In allowing for actual horsepower, multiply the theoretical by 2 for lifts up to 50 feet; by 1¾ for lifts up to 125 feet, and by 1½ for higher lifts

Gallons per Minute	Total Height of Elevation, Suction to Delivery, in Feet											
	10	20	30	40	50	60	75	100	125	150	200	300
	Theoretical Horsepower											
5	0.012	0.025	0.037	0.05	0.06	0.07	0.09	0.12	0.16	0.19	0.25	0.37
15	.037	.075	.112	.15	.19	.22	.28	.37	.47	.56	.75	1.12
25	.062	.125	.187	.25	.31	.37	.47	.62	.78	.94	1.25	1.78
35	.087	.175	.262	.35	.44	.52	.66	.87	1.08	1.31	1.75	2.62
50	.125	.250	.375	.50	.62	.75	.94	1.25	1.56	1.87	2.50	3.75
75	.187	.375	.562	.75	.94	1.12	1.40	1.87	2.34	2.81	3.75	5.62
100	.250	.500	.750	1.00	1.25	1.50	1.87	2.50	3.12	3.75	5.00	7.50
150	.375	.750	1.12	1.50	1.87	2.25	2.81	3.75	4.69	5.62	7.50	11.25
200	.500	1.00	1.50	2.00	2.50	3.00	3.75	5.00	6.25	7.50	10.00	15.00
250	.625	1.25	1.87	2.50	3.12	3.75	4.69	6.25	7.81	9.37	12.50	18.75
300	.750	1.50	2.25	3.00	3.75	4.50	5.62	7.50	9.37	11.25	15.00	22.50
400	1.00	2.00	3.00	4.00	5.00	6.00	7.50	10.00	12.50	15.00	20.00	30.00
500	1.25	2.50	3.75	5.00	6.25	7.50	9.37	12.50	15.62	18.75	25.00	37.50

Duplex Steam Pumps

Diagrams for Determining Sizes and Speeds Necessary for Various Service Requirements

The diagrams refer only to duplex, direct-connected steam pumps, and assume a pump efficiency of 75%.

To illustrate the method of using the diagrams the following example will serve:

EXAMPLE—What should be the dimensions and speed of a duplex steam pump to deliver a maximum of 175 gallons of water per minute against a head equal to a pressure of 300 pounds per square inch, if the available steam pressure is 100 pounds?

(A) WATER CYLINDER DIAMETER—Starting at the upper left side of Diagram 1, at the point for 175 gallons per minute, trace horizontally to the right to the line that curves from the upper left to the lower right; thence vertically down to the center of the diagram, to find the proper diameter of water cylinder—5.5 inches.

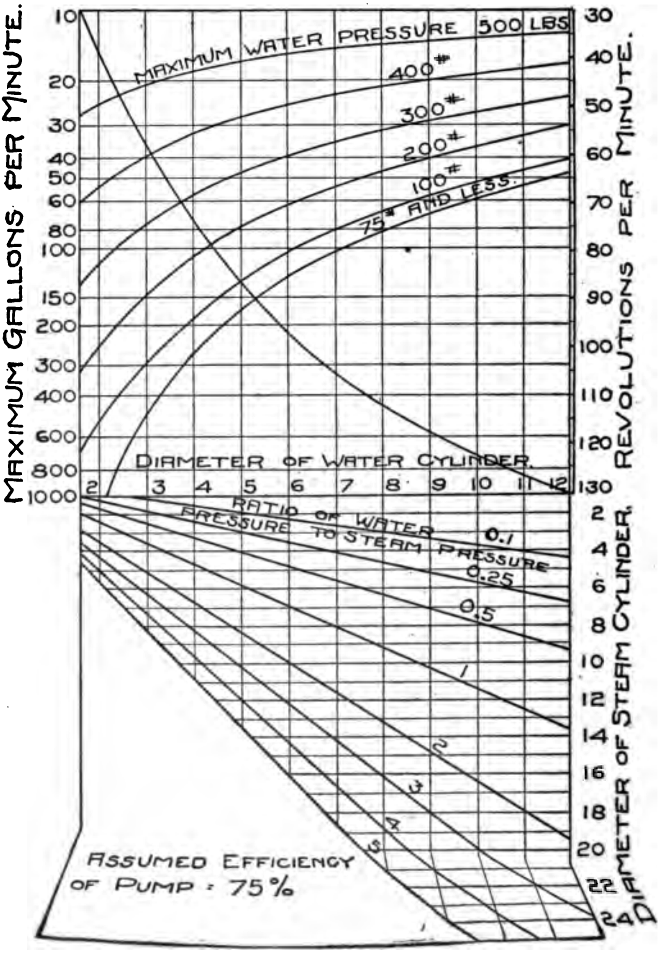
(B) STEAM CYLINDER DIAMETER—Continue thence vertically down to the diagonal which represents the ratio of the water pressure to the steam pressure. In this example the ratio is 300 to 100, or 3. From the intersection with this diagonal (3) trace horizontally to the right side of the diagram, to find the steam cylinder diameter—11 inches.

(C) SPEED—From the same intersection with the curved line in the upper part of the diagram, horizontally in from the point for 175 gallons per minute at the left, trace vertically to the diagonal for 300 pounds water pressure; thence horizontally to the right side of the diagram, to find the proper speed of running—62 r. p. m.

(D) STROKE—Starting at the left side of Diagram 2, at the point for 175 gallons per minute, trace horizontally to the right to the diagonal for 5.5-in. diameter of wate cylinder; thence vertically to the point where a diago

Duplex Steam Pumps—Continued

Diagram 1. Diameters of Steam and Water Cylinders, and Speeds Necessary for Various Pressures and Volumes.



Duplex Steam Pumps—Continued

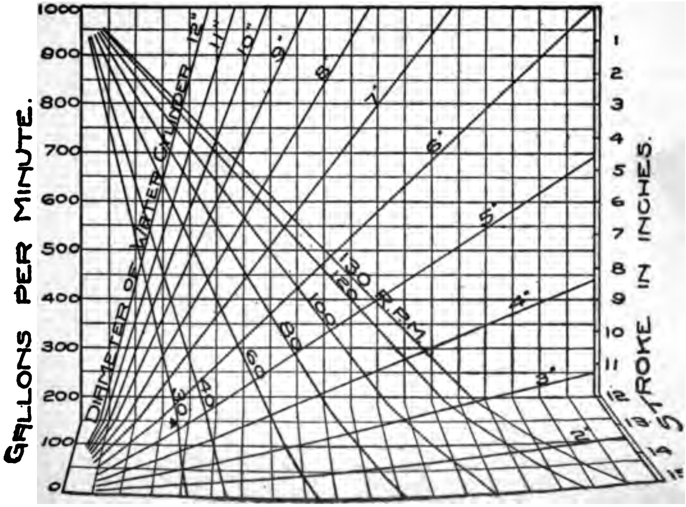
for 62 r. p. m. would intersect; thence horizontally to the right side, to find the stroke—7.2 in.

Thus the combined use of the two diagrams shows that a duplex pump 11 x 5½ x 7½ in. should be used, at 62 r. p. m.

If the head is expressed in feet of water, reduce this to pounds per square inch by multiplying the head in feet by .433, or by use of the conversion table on page 79.

Diagram 2

Lengths of Stroke Necessary to Give Desired Volume with Various Water Cylinder Diameters and at Various Speeds



Diameters and Speeds

Rules for Size and Speed Determinations for Pulleys, Sheaves, Gears and Sprocket Wheels

The driving wheel is called the driver, and the receiving wheel the driven.

Diameters must be measured in like units, as inches or feet, for both wheels, and speeds must also be in like units, as rotations per minute.

Number of teeth in gears or sprocket wheels may be used instead of diameters in these calculations, but the substitution, if made at all, must be made for both driver and driven.

1. To determine the diameter of the driver, when the diameter of the driven and the speeds of both driver and driven are given:

$$\frac{\text{Diameter of driven} \times \text{rotations of driven}}{\text{Rotations of driver}} = \text{Diameter of driver.}$$

2. To determine the diameter of the driven, when the diameter of the driver and the speeds of both driver and driven are given:

$$\frac{\text{Diameter of driver} \times \text{rotations of driver}}{\text{Rotations of driven}} = \text{Diameter of driven.}$$

3. To determine the speed of the driver, when the speed of the driven and the diameters of both driver and driven are given:

$$\frac{\text{Diameter of driven} \times \text{rotations of driven}}{\text{Diameter of driver}} = \text{Rotations of driver.}$$

4. To determine the speed of the driven, when the speed of the driver and the diameters of both driver and driven are given:

$$\frac{\text{Diameter of driver} \times \text{rotations of driver}}{\text{Diameter of driven}} = \text{Rotations of driven.}$$

Linear Speeds of Rotation

Pulley Rims or Pitch Lines of Gears, etc.

For intermediate diameters or rotations, or for values outside the limits of the table, use proportionate values.

Diam. In.	Rotations per Minute								
	100	125	150	175	200	250	300	350	400
	Linear Speed, Feet per Minute								
6	157.1	196.3	235.6	274.9	314.2	392.7	471.2	549.8	628.3
7	183.3	229.1	274.9	320.7	366.5	458.1	549.8	641.4	733.0
8	209.4	261.8	314.2	366.5	418.9	523.6	628.3	733.0	837.8
9	235.6	294.5	353.4	412.3	471.2	589.0	706.8	824.7	942.5
10	261.8	327.2	392.7	458.1	523.6	654.5	785.4	916.3	1047.2
11	288.0	360.0	432.0	504.0	576.0	720.0	863.9	1007.9	1151.9
12	314.2	392.7	471.2	549.8	628.3	785.4	942.5	1099.6	1256.6
13	340.3	425.4	510.5	595.6	680.7	850.8	1021.0	1191.2	1361.4
14	366.5	458.1	549.8	641.4	733.0	916.3	1099.6	1282.8	1466.1
15	392.7	490.8	589.0	687.2	785.4	981.7	1178.1	1374.4	1570.8
16	418.9	523.6	628.3	733.0	837.8	1047.2	1256.6	1466.1	1675.5
17	445.1	556.3	667.6	778.8	890.1	1112.7	1335.2	1557.7	1780.2
18	471.2	589.0	706.8	824.6	942.5	1178.1	1413.7	1649.3	1885.0
19	497.4	621.7	746.1	870.5	994.8	1243.5	1492.3	1741.0	1989.7
20	523.6	654.5	785.4	916.3	1047.2	1309.0	1570.08	1832.6	2094.4
22	576.0	720.0	864.0	1007.9	1151.9	1439.9	1727.9	2015.9	2303.8
24	628.3	785.4	942.5	1099.6	1256.6	1570.8	1885.0	2199.1	2513.3
26	680.7	850.8	1021.0	1191.2	1361.4	1701.7	2042.0	2382.4	2722.7
28	733.0	916.3	1099.6	1282.8	1466.1	1832.6	2199.1	2565.7	2932.2
30	785.4	981.7	1178.1	1374.4	1570.8	1963.5	2356.2	2748.9	3141.6
32	837.8	1047.2	1256.6	1466.1	1675.5	2094.4	2513.3	2932.1	3351.0
34	890.1	1112.6	1335.2	1557.7	1780.2	2225.3	2670.4	3115.4	3560.5
36	942.5	1178.1	1413.7	1649.3	1885.0	2356.2	2827.4	3298.7	3769.9
38	994.8	1241.0	1487.3	1738.5	1989.7	2482.1	2974.5	3477.0	3979.4
40	1047.2	1309.0	1570.8	1832.6	2094.4	2618.0	3141.6	3665.2	4188.8
42	1099.6	1374.4	1649.3	1924.2	2199.1	2748.9	3298.7	3848.5	4398.2
44	1151.9	1439.9	1727.9	2015.9	2303.8	2879.8	3455.8	4031.8	4607.7
46	1204.2	1505.3	1806.4	2107.5	2408.6	3010.7	3612.8	4215.0	4817.1
48	1256.6	1570.8	1885.0	2199.1	2513.3	3141.6	3769.9	4398.2	5026.5
50	1309.0	1636.2	1963.5	2290.7	2618.0	3272.5	3927.0	4581.5	5236.0
52	1361.4	1701.7	2042.0	2382.4	2722.7	3403.4	4084.1	4764.8	5445.4
54	1413.7	1767.1	2120.6	2474.0	2827.5	3534.3	4241.2	4948.0	5654.9
56	1466.1	1832.6	2199.1	2565.6	2932.2	3665.2	4398.2	5131.2	5864.3
58	1518.4	1898.0	2277.7	2657.3	3036.9	3796.1	4555.3	5314.5	6073.7
60	1570.8	1963.5	2356.2	2748.9	3141.6	3927.0	4712.4	5497.8	6283.2
64	1675.5	2094.4	2513.3	2932.2	3351.0	4188.8	5026.5	5864.3	6702.1
68	1780.2	2225.3	2670.4	3115.4	3560.5	4450.6	5340.7	6230.8	7120.9
72	1885.0	2356.2	2827.4	3298.7	3769.9	4712.4	5654.9	6597.3	7539.8
76	1989.7	2487.1	2984.5	3481.9	3979.4	4974.2	5969.0	6963.9	7958.7
80	2094.4	2618.0	3141.6	3665.2	4188.8	5236.0	6283.2	7330.4	8377.6
84	*2199.1*	*2748.9*	3298.7	3848.4	4398.2	5497.8	6597.3	7696.9	8796.5
88	*2303.8*	*2879.8*	*3455.8*	4031.7	4607.7	5759.6	6911.5	8063.4	9215.3
92	*2408.6*	*3010.7*	*3612.8*	4215.0	4817.1	6021.4	7225.7	8430.0	9634.2
96	*2513.3*	*3141.6*	*3769.9*	4398.2	5020.5	6283.2	7539.8	8796.5	10053.
100	*2618.0*	*3272.5*	*3927.0*	4581.5	5236.0	6545.0	7854.0	9163.0	10472

Horsepower of Leather Belting

Single Belts

Single Belt 1 Inch Wide Gives 1 H. P. at 800 Ft. per Min.

Belt Speed, Feet per Minute	Belt Width, Inches							
	3	4	5	6	7	8	9	10
600	2.4	3.2	4.0	4.8	5.6	6.4	7.1	7.9
900	3.6	4.7	5.9	7.1	8.3	9.5	10.6	11.8
1200	4.7	6.3	7.9	9.4	11.0	12.6	14.2	15.7
1500	5.8	7.8	9.7	11.6	13.6	15.5	17.5	19.4
1800	6.9	9.3	11.5	13.9	16.2	18.5	20.8	23.1
2100	7.5	10.7	13.3	16.5	18.6	21.8	23.9	26.6
2400	9.0	12.0	15.1	18.1	21.1	24.1	27.1	30.1
2700	9.9	13.2	16.6	19.9	23.2	26.5	29.8	33.1
3000	10.8	14.4	18.1	21.7	25.3	28.9	32.5	36.1
3300	11.7	15.5	19.4	23.3	27.2	31.1	34.9	38.8
3600	12.5	16.6	20.8	24.9	29.1	33.2	37.4	41.5
4200	13.8	18.4	23.0	27.6	32.2	36.8	41.4	46.0
4800	14.7	19.6	24.5	29.4	34.3	39.0	44.1	49.0
5400	15.3	20.4	25.5	30.6	35.7	40.8	45.9	51.0
6000	15.3	20.4	25.5	30.6	35.7	40.8	45.9	51.0

Belt Speed, Feet per Minute	Belt Width, Inches							
	11	12	14	16	18	20	22	24
600	8.7	9.5	11.1	12.7	14.3	15.9	17.4	19.0
900	13.0	14.2	16.6	18.9	21.3	23.6	26.0	28.4
1200	17.3	18.9	22.0	25.2	28.3	31.4	34.6	37.7
1500	21.3	23.3	27.7	31.0	34.9	38.8	42.7	46.5
1800	25.3	27.7	32.3	36.9	41.5	46.2	50.8	55.3
2100	29.2	31.9	37.2	42.5	47.8	53.2	58.5	64.2
2400	33.1	36.1	42.1	48.2	54.2	60.2	66.2	72.2
2700	36.4	39.7	46.1	52.9	59.6	66.2	72.8	79.9
3000	39.7	43.3	50.1	57.7	65.0	72.2	79.3	86.6
3300	42.7	46.5	54.2	62.1	69.9	77.6	81.3	93.1
3600	45.7	49.8	58.2	66.4	74.7	83.0	91.3	99.6
4200	50.6	55.2	64.4	73.6	82.8	92.0	101.2	110.4
4800	53.9	58.8	68.6	78.4	88.2	98.0	107.8	117.6
5400	56.1	61.2	71.4	81.6	91.8	102.0	112.2	122.4
6000	56.1	61.2	71.4	81.6	91.8	102.0	112.2	122.4

Horsepower of Leather Belting

Double Belts

Double Belt 1 Inch Wide gives 1 H. P. at 560 Ft. per Min.

Belt Speed, Feet per Minute	Belt Width, Inches									
	6	7	8	9	10	12	14	16	18	20
600	8.2	9.5	10.9	12.2	13.6	16.3	19.0	21.7	24.4	27.1
900	12.2	14.2	16.2	18.2	20.3	24.3	28.4	32.4	36.5	40.5
1200	16.2	18.8	21.5	24.2	26.9	32.3	37.7	43.1	48.5	53.9
1500	19.8	23.2	26.5	29.8	33.1	39.7	46.4	53.0	59.6	66.2
1800	23.7	27.6	31.6	35.5	39.5	47.4	55.3	63.2	71.1	79.0
2100	27.4	31.9	36.5	41.0	45.6	54.7	63.8	72.9	82.0	91.1
2400	31.0	36.1	41.3	46.4	51.6	61.9	72.2	82.5	92.8	103.1
2700	34.0	39.7	45.3	51.0	56.7	68.0	79.3	90.7	102.0	113.3
3000	37.2	43.3	49.5	55.7	61.9	74.3	86.6	99.0	111.4	123.8
3300	39.9	46.6	53.2	59.9	66.5	79.8	93.1	106.4	119.7	133.1
3600	42.8	49.9	57.0	64.1	71.3	85.5	99.8	114.0	128.3	142.5
4200	47.4	55.3	63.2	71.0	78.9	94.7	110.5	126.3	142.1	157.9
4800	50.4	58.8	67.2	75.6	84.0	100.8	117.6	134.4	151.2	168.0
5400	52.2	61.2	69.9	78.6	87.4	104.8	122.3	139.8	157.3	174.7
6000	52.4	61.2	69.9	78.6	87.4	104.8	122.3	139.8	157.3	174.7

Belt Speed, Feet per Minute	Belt Width, Inches									
	22	24	26	28	30	32	36	40	44	48
600	29.9	32.6	35.3	38.0	40.7	43.4	48.9	54.3	59.7	65.1
900	44.6	48.6	52.7	56.7	60.7	64.8	72.9	81.0	89.1	97.2
1200	59.2	64.6	70.0	75.4	80.8	86.2	96.9	107.7	118.5	129.2
1500	72.8	79.5	86.1	92.7	99.3	106.0	119.2	132.4	145.7	158.9
1800	86.9	94.8	102.7	110.4	118.5	126.4	142.1	157.9	173.7	189.6
2100	100.2	109.3	118.5	127.6	136.7	145.8	164.0	182.2	200.5	218.7
2400	113.4	123.7	134.1	144.4	154.7	165.0	185.6	206.2	226.9	247.5
2700	124.7	136.0	147.3	158.7	170.0	181.3	204.0	226.6	249.3	272.0
3000	136.1	148.5	160.9	173.3	185.6	198.0	212.8	237.5	262.3	287.0
3300	146.4	159.7	173.0	186.3	199.6	212.9	239.5	266.1	292.7	319.3
3600	156.8	171.0	185.3	199.5	213.8	228.0	256.5	285.0	313.5	342.0
4200	173.7	189.5	205.2	221.0	236.8	252.6	284.2	315.8	347.3	378.9
4800	184.8	201.6	218.4	235.2	252.0	268.8	302.4	336.0	369.6	403.2
5400	*192.2*	*209.7*	227.2	244.6	262.1	279.6	314.5	349.5	384.4	419.4
6000	*192.2*	209.7	227.2	244.6	262.1	279.6	314.5	349.5	384.4	419.[illegible]

Horsepower of Shafting

1. Headshafts

Headshafts are those which receive or deliver power in relatively large units, as in jackshafts or the receiving-pulley sections of lineshafts, where bearings may be placed close, to relieve the shaft of the bending action due to the tension of belts or ropes and the weight of pulleys, sheaves, etc.

Horsepower = cube of diameter in inches × speed in rotations per minute ÷ 125.

Shaft Diameter, Inches	SPEED, ROTATIONS PER MINUTE							
	100	125	150	175	200	250	300	400
2 3/16	8.18	10.2	12.3	14.3	16.4	20.5	24.5	32.7
2 7/16	11.6	14.5	17.4	20.3	23.2	29.0	34.8	46.4
2 11/16	15.5	19.4	23.3	27.2	31.1	38.8	46.6	62.1
2 15/16	20.3	25.4	30.4	35.5	40.6	50.7	60.8	81.1
3 3/16	25.9	32.4	38.9	45.3	51.8	64.8	77.7	104
3 7/16	32.5	40.6	48.8	56.9	65.0	81.3	97.5	130
3 11/16	40.1	50.1	60.2	70.2	80.2	100	120	160
3 15/16	48.8	61.1	73.3	85.5	97.7	122	147	195
4 3/16	58.7	73.4	88.1	103	117	147	176	235
4 7/16	69.9	87.4	105	122	140	175	210	280
4 11/16	82.4	103	124	144	165	206	247	330
4 15/16	96.3	120	144	169	193	241	289	385
5 3/16	112	140	168	195	223	279	335	447
5 7/16	129	161	193	225	257	322	386	514
5 11/16	147	184	221	258	294	368	442	589
6	167	209	251	293	335	419	502	670
6 1/2	220	275	330	384	439	549	659	879
7	277	346	416	485	555	694	832	......
7 1/2	338	422	506	591	675	844	......	......
8	410	512	614	717	819	......	......	......

Horsepower of Shafting

2. Lineshafts

Supported by Bearings every 8 to 10 Feet

Lineshafts are those from which power in relatively small units is delivered at various intervals, in various directions, from pulleys not always close to bearings.

Horsepower = cube of diameter in inches × speed in rotations per minute ÷ 90.

Shaft Diameter, Inches	SPEED, ROTATIONS PER MINUTE							
	100	125	150	175	200	250	300	400
1 3/16	1.86	2.33	2.79	3.26	3.72	4.65	5.58	7.44
1 7/16	3.30	4.13	4.95	5.78	6.60	8.25	9.90	13.2
1 11/16	5.34	6.67	8.01	9.34	10.7	13.3	16.0	21.4
1 15/16	8.08	10.1	12.1	14.1	16.2	20.2	24.2	32.3
2 3/16	11.6	14.5	17.4	20.4	23.3	29.1	34.9	46.5
2 7/16	16.1	20.1	24.1	28.2	32.2	40.2	48.3	64.4
2 11/16	21.6	27.0	32.4	37.7	43.1	53.9	64.7	86.3
2 15/16	28.2	35.2	42.2	49.3	56.3	70.4	84.5	113
3 3/16	36.0	45.0	54.0	63.0	72.0	90.0	108	143
3 7/16	45.1	56.4	67.7	79.0	90.3	113	135	181
3 11/16	55.7	69.6	83.6	97.5	111	139	167	223
3 15/16	67.8	84.8	102	119	136	170	203	271
4 3/16	81.6	102	122	143	163	204	245	326
4 7/16	97.1	121	146	170	194	242	291	388
4 11/16	114	143	172	200	229	286	343	458
4 15/16	134	167	201	234	267	334	401	534
5 3/16	155	194	233	271	310	388	465	621
5 7/16	179	223	268	313	357	447	536	714
5 11/16	204	256	307	358	409	515	617	822
6	233	291	349	408	466	583	699	931

Horsepower of Shafting

3. Transmission Shafts

Supported by bearings every 10 to 12 feet

Transmission shafts are those which, carried in regularly spaced bearings and simply transmitting power, are subject to no bending stresses due to receipt or delivery of power at intermediate points.

Horsepower = cube of diameter in inches × speed in rotations per minute ÷ 60.

Shaft Diameter, Inches	SPEED, ROTATIONS PER MINUTE							
	100	125	150	175	200	250	300	400
1 3/16	2.79	3.49	4.19	4.88	5.58	6.98	8.37	11.2
1 7/16	4.95	6.19	7.43	8.66	9.90	12.4	14.9	19.8
1 11/16	8.01	10.0	12.0	14.0	16.0	20.0	24.0	32.0
1 15/16	12.1	15.2	18.2	21.2	24.2	30.3	36.4	48.5
2 3/16	17.4	21.8	26.2	30.5	34.9	43.6	52.3	69.9
2 7/16	24.1	30.2	36.2	42.2	48.3	60.4	72.4	96.6
2 11/16	32.4	40.4	48.5	56.6	64.7	80.9	97.4	129
2 15/16	42.2	52.8	63.4	73.9	84.5	106	127	169
3 3/16	54.0	67.5	81.0	94.5	108	135	162	216
3 7/16	76.7	95.9	114	133	152	191	229	306
3 11/16	83.6	104	125	146	167	209	251	334
3 15/16	102	127	153	178	203	254	305	407
4 3/16	122	153	184	214	245	306	367	490
4 7/16	146	182	218	255	291	364	437	582
4 11/16	172	215	256	300	343	429	515	687
4 15/16	201	251	301	351	401	502	602	802
5 3/16	233	291	349	407	465	582	698	931
5 7/16	268	335	402	469	536	670	804	......
5 11/16	307	383	460	537	613	767	920	......
6	349	439	528	618	708	887	......	......

Toothed Gearing

Pitch Diameters for 1-Inch Circular Pitch

For any other pitch, multiply by that pitch

Number of Teeth	Pitch Diameter, Inches	Number of Teeth	Pitch Diameter, Inches	Number of Teeth	Pitch Diameter, Inches	Number of Teeth	Pitch Diameter, Inches	Number of Teeth	Pitch Diameter, Inches
11	3.50	26	8.28	41	13.05	56	17.83	71	22.60
12	3.82	27	8.60	42	13.37	57	18.14	72	22.92
13	4.14	28	8.91	43	13.69	58	18.46	73	23.24
14	4.46	29	9.23	44	14.00	59	18.78	74	23.56
15	4.78	30	9.55	45	14.33	60	19.10	75	23.88
16	5.09	31	9.87	46	14.67	61	19.42	76	24.19
17	5.41	32	10.19	47	14.96	62	19.74	77	24.51
18	5.73	33	10.50	48	15.28	63	20.06	78	24.83
19	6.05	34	10.82	49	15.60	64	20.37	79	25.15
20	6.37	35	11.14	50	15.92	65	20.69	80	25.47
21	6.69	36	11.46	51	16.24	66	21.01	81	25.79
22	7.00	37	11.78	52	16.55	67	21.33	82	26.10
23	7.32	38	12.10	53	16.87	68	21.65	83	26.42
24	7.64	39	12.42	54	17.19	69	21.97	84	26.74
25	7.96	40	12.73	55	17.51	70	22.28	85	27.06

Diametral and Circular Pitch Equivalents

Diametral Pitch is the number of teeth per inch of pitch diameter

Diametral Pitch	Circular Pitch, Inches	Diametral Pitch	Circular Pitch, Inches	Diametral Pitch	Circular Pitch, Inches	Diametral Pitch	Circular Pitch, Inches
½	6.2832	2½	1.2566	8	.3927	20	.1571
¾	4.1888	2¾	1.1424	9	.3491	22	.1428
1	3.1416	3	1.0472	10	.3142	24	.1309
1¼	2.5133	3½	.8976	11	.2856	26	.1208
1½	2.0944	4	.7854	12	.2618	28	.1122
1¾	1.7952	5	.6283	14	.2244	30	.1047
2	*1.5708*	*6*	.5236	16	.1963	32	.0982
2¼	*1.3963*	*7*	.4488	18	.1745	36	.0873

Horsepower of Cast Iron Gears

Spur Gears with Molded Teeth

For gears larger than given, take double the horsepower of a gear of half the size.

Proportionate horsepowers for other speeds and for other face iᴧᴧdths.

For miter and bevel iron gears, multiply tabular horsepowers by 0.7. For gears of cast steel, multiply by 2½.

Number of Teeth	Circular Pitch, Inches								
	¾	⅞	1	1¼	1½	1¾	2	2½	3
	Face Width, Inches								
	1½	2	2½	3	4	5	6	7½	9
	Horsepower per 100 R. P. M.								
10	0.4	0.8	1.3	2.5	4.7	8.1	11.5	22.5	40.5
11	.5	.9	1.4	2.7	5.2	8.9	12.7	24.8	41.6
12	.5	1.0	1.6	3.0	5.7	9.7	13.8	27.0	48.7
13	.6	1.1	1.7	3.2	6.1	10.5	15.0	29.3	52.7
14	.6	1.1	1.8	3.4	6.6	11.3	16.1	31.5	56.8
15	.7	1.2	2.0	3.7	7.1	12.1	17.3	33.8	60.8
16	.7	1.3	2.1	3.9	7.6	12.9	18.4	36.0	64.9
17	.7	1.4	2.2	4.2	8.0	13.7	19.6	38.3	68.9
18	.8	1.5	2.4	4.4	8.5	14.5	20.7	40.5	72.9
19	.8	1.5	2.5	4.7	9.0	15.3	21.9	42.8	77.0
20	.9	1.6	2.6	4.9	9.5	16.1	23.0	45.0	81.0
21	.9	1.7	2.8	5.2	9.9	16.9	24.2	47.3	84.1
22	1.0	1.8	2.9	5.4	10.4	17.7	25.3	49.5	89.1
23	1.0	1.9	3.0	5.7	10.8	18.5	26.5	51.8	93.2
24	1.1	2.0	3.1	5.9	11.3	19.3	27.6	54.0	98.2
25	1.1	2.0	3.3	6.1	11.8	20.1	28.8	56.3	101.2
26	1.1	2.1	3.4	6.4	12.2	20.9	29.9	58.5	105.3
27	1.2	2.2	3.5	6.6	12.7	21.7	31.1	60.8	109.3
28	1.2	2.3	3.7	6.9	13.2	22.5	32.2	63.0	113.4
29	1.3	2.4	3.8	7.1	13.7	23.4	33.4	65.3	117.4
30	1.3	2.4	3.9	7.4	14.1	24.2	34.5	67.5	121.5
31	1.4	2.5	4.1	7.6	14.6	25.0	35.7	69.8	125.5
32	1.4	2.6	4.2	7.9	15.1	25.8	36.8	72.0	129.6
33	1.5	2.7	4.3	8.1	15.5	26.6	38.0	74.3	133.6
34	1.5	2.8	4.5	8.4	16.0	27.4	39.1	76.5	137.6
35	1.5	2.8	4.6	8.6	16.5	28.2	40.2	78.8	141.7

Horsepower of Cast Iron Gears
Continued

Number of Teeth	Circular Pitch, Inches								
	¾	⅞	1	1¼	1½	1¾	2	2½	3
	Face Width, Inches								
	1½	2	2½	3	4	5	6	7½	9
	Horsepower per 100 R. P. M.								
36	1.6	2.9	4.7	8.9	16.9	29.0	41.4	81.0	145.8
37	1.6	3.0	4.8	9.1	17.4	29.8	42.5	83.3	149.8
38	1.7	3.1	5.0	9.3	17.9	30.6	43.7	85.5	153.9
39	1.7	3.2	5.1	9.6	18.4	31.4	44.8	87.8	157.9
40	1.8	3.3	5.2	9.8	18.8	32.2	46.0	90.0	162.0
41	1.8	3.3	5.4	10.1	19.3	33.0	47.1	92.3	166.0
42	1.8	3.4	5.5	10.3	19.8	33.8	48.3	94.5	170.0
43	1.9	3.5	5.6	10.6	20.2	34.6	49.4	96.8	174.1
44	1.9	3.6	5.8	10.8	20.7	35.4	50.6	99.0	178.1
45	2.0	3.7	5.9	11.1	21.2	36.2	51.7	101.3	182.2
46	2.0	3.7	6.0	11.3	21.7	37.0	52.9	103.5	186.2
47	2.1	3.8	6.2	11.6	22.1	37.8	54.0	105.7	190.3
48	2.1	3.9	6.3	11.8	22.6	38.6	55.2	108.0	194.3
49	2.2	4.0	6.4	12.0	23.1	39.4	56.3	110.3	198.4
50	2.2	4.1	6.5	12.3	23.5	40.2	57.5	112.5	202.4
51	2.2	4.2	6.7	12.5	24.0	41.1	58.6	114.8	206.5
52	2.3	4.2	6.8	12.8	24.5	41.9	59.8	117.0	210.5
53	2.3	4.3	6.9	13.0	25.0	42.7	60.9	119.3	214.6
54	2.4	4.4	7.1	13.3	25.4	43.5	62.1	121.5	218.6
55	2.4	4.5	7.2	13.5	25.9	44.3	63.2	123.8	222.7
56	2.5	4.6	7.3	13.8	26.4	45.1	64.4	126.0	226.7
57	2.5	4.6	7.5	14.0	26.8	45.9	65.6	127.3	230.8
58	2.6	4.7	7.6	14.3	27.3	46.7	66.7	130.5	234.8
59	2.6	4.8	7.7	14.5	27.8	47.5	67.8	132.8	238.9
60	2.6	4.9	7.9	14.8	28.3	48.3	69.0	135.0	242.9
61	2.7	5.0	8.0	15.0	28.7	49.1	70.1	137.3	247.0
62	2.7	5.0	8.1	15.3	29.2	49.9	71.3	139.5	251.0
63	2.8	5.1	8.3	15.5	29.7	50.7	72.4	141.8	255.1
64	2.8	5.2	8.4	15.8	30.1	51.5	73.6	144.0	259.1
65	2.9	5.3	8.5	16.0	30.6	52.3	74.7	146.3	263.2

Weights of Steel Angles

With Fillet

Pounds per Lineal Foot

Size, Inches	Thickness, Inches								
	1/8	3/16	1/4	5/16	3/8	7/16	1/2	5/8	3/4
5/8x 5/8	0.5	.....	.....	.....	.....	.....	.....	.....	.....
3/4x 3/4	0.6	0.8	.....	.....	.....	.....	.....	.....	.....
7/8x 7/8	0.7	1.0	.....	.....	.....	.....	.....	.....	.....
1 x1	0.8	1.2	1.5	.....	.....	.....	.....	.....	.....
1 1/8x1 1/8	0.9	1.3	1.7	2.1	.....	.....	.....	.....	.....
1 1/4x1 1/4	1.0	1.5	1.9	2.4	.....	.....	.....	.....	.....
1 1/2x1 1/2	1.2	1.8	2.4	2.9	3 4	.....	.....	.....	.....
1 3/4x1 3/4	1.4	2.1	2.8	3.4	4.0	4.6	.....	.....	.....
2 x1 1/2	.....	2.1	2.8	3.4	4.0	.....	.....	.....	.....
x2	1.7	2.5	3.2	4.0	4.7	5.3	.....	.....	.....
2 1/4x1 1/2	.....	2.3	3.0	3.7	4.3	5.0	5.5	.....	.....
x2 1/4	1.9	2.8	3.7	4.5	5.3	6.1	6.8	.....	.....
2 1/2x1 1/2	.....	2.4	3.2	3.9	4.6	5.3	6.0	.....	.....
x1 3/4	.....	2.6	.....	.....	.....	.....	.....	.....	.....
x2	.....	2.8	3.7	4.5	5.3	6.1	6.8	.....	.....
x2 1/2	2.1	3.0	4.1	5.0	5.9	6.8	7.7	9.3	.....
2 3/4x2 3/4	2.4	3.5	4.5	5.5	6.6	7.6	8.5	.....	.....
3 x2	.....	3.1	4.1	5.0	5.9	6.8	7.7	.....	.....
x2 1/2	.....	.....	4.5	5.5	6.6	7.6	8.5	.....	.....
x3	2.6	.....	4.9	6.1	7.2	8.4	9.4	11.4	13.4
3 1/2x2 1/2	.....	.....	4.9	6.1	7.2	8.3	9.4	11.4	.....
x3	.....	.....	.....	6.6	7.8	9.1	10.2	12.5	14.7
x3 1/2	.....	.....	5.7	7.1	8.5	9.8	11.1	13.6	16.0
4 x3	.....	.....	.....	7.1	8.5	9.8	11.1	13.6	16.0
x3 1/2	.....	.....	.....	.....	9.1	10.5	11.9	14.6	17.2
x4	.....	5.2	6.6	8.2	9.8	11.3	12.8	15.7	18.5
5 x3	.....	.....	.....	8.2	9.8	11.3	12.8	15.7	18.5
x4	.....	.....	.....	.....	11.0	12.8	14.5	17.8	21.1
x5	.....	.....	.....	.....	12.3	14.3	16.2	20.0	23.6
6 x4	.....	.....	.....	.....	12.3	14.3	16.2	20.1	23.6
x6	.....	.....	.....	.....	14.4	17.2	19.6	24.2	28.7

Weights of Round and Square Iron

¼-inch steel plate weighs approximately 10 pounds per square foot

The weight of all rolled steel, in pounds per running foot, is approximately 3⅓ times the sectional area in square inches

Size, Inches	Weight, Pounds per Lineal Foot: Round	Weight, Pounds per Lineal Foot: Square	Size, Inches	Weight, Pounds per Lineal Foot: Round	Weight, Pounds per Lineal Foot: Square
3/16	.094	.120	2 1/8	12.06	15.35
1/4	.167	.213	2 1/4	13.52	17.22
5/16	.261	.332	2 3/8	15.07	19.18
3/8	.376	.478			
			2 1/2	16.69	21.25
7/16	.511	.651	2 5/8	18.40	23.43
1/2	.668	.850	2 3/4	20.20	25.71
9/16	.845	1.076	2 7/8	22.07	28.10
5/8	1.043	1.328			
			3	24.03	30.60
11/16	1.262	1.607	3 1/4	28.20	35.92
3/4	1.502	1.913	3 1/2	32.71	41.65
13/16	1.763	2.245	3 3/4	37.56	47.82
7/8	2.044	2.603			
			4	42.73	54.40
15/16	2.347	2.989	4 1/4	48.24	61.41
1	2.670	3.400	4 1/2	54.07	68.85
1 1/16	3.014	3.838	4 3/4	60.25	76.71
1 1/8	3.379	4.303			
			5	66.76	85.00
1 3/16	3.766	4.795	5 1/4	73.60	93.72
1 1/4	4.173	5.312	5 1/2	80.77	102.80
1 5/16	4.600	5.857	5 3/4	88.29	112.4
1 3/8	5.049	6.428			
			6	96.14	122.4
1 7/16	5.518	7.026	6 1/2	112.8	143.6
1 1/2	6.008	7.650	7	130.9	166.6
1 9/16	6.520	8.301	7 1/2	150.2	191.3
1 5/8	7.051	8.978			
			8	171.0	217.6
1 3/4	8.178	10.41	8 1/2	193.0	245.6
1 7/8	9.388	11.95	10	267.0	340.0
2	10.68	13.60	12	384.6	489.6

Weights of Flat Steel

Pounds per Linear Foot

Weight Basis—489.6 Pounds per Cubic Foot

Width, Inches	Thickness, Inches							
	1/8	3/16	1/4	5/16	3/8	1/2	3/4	1
1/2	.212	.319	.425	.531	.638	.850	1.28	1.70
5/8	.266	.398	.531	.664	.797	1.06	1.59	2.12
3/4	.319	.478	.638	.797	.956	1.28	1.92	2.55
1	.424	.638	.850	1.06	1.28	1.70	2.55	3.40
1 1/4	.532	.797	1.06	1.32	1.59	2.12	3.19	4.25
1 1/2	.638	.956	1.28	1.59	1.92	2.55	3.83	5.10
1 3/4	.744	1.12	1.48	1.86	2.23	2.98	4.47	5.95
2	.850	1.28	1.70	2.12	2.55	3.40	5.10	6.80
2 1/4	.956	1.44	1.91	2.39	2.87	3.83	5.75	7.65
2 1/2	1.06	1.59	2.12	2.65	3.19	4.25	6.38	8.50
2 3/4	1.168	1.75	2.34	2.92	3.51	4.67	7.02	9.35
3	1.28	1.91	2.55	3.19	3.83	5.10	7.65	10.20
3 1/4	1.38	2.08	2.76	3.45	4.15	5.53	8.29	11.05
3 1/2	1.48	2.24	2.98	3.72	4.47	5.95	8.93	11.90
3 3/4	1.59	2.40	3.19	3.99	4.78	6.38	9.57	12.75
4	1.70	2.55	3.40	4.25	5.10	6.80	10.20	13.60
4 1/2	1.91	2.87	3.82	4.78	5.74	7.65	11.48	15.30
5	2.12	3.18	4.24	5.31	6.38	8.50	12.75	17.00
5 1/2	2.34	3.51	4.67	5.84	7.02	9.35	14.03	18.70
6	2.55	3.83	5.10	6.35	7.65	10.20	15.30	20.40
6 1/2	2.76	4.14	5.53	6.90	8.29	11.05	16.58	22.10
7	2.97	4.46	5.95	7.44	8.93	11.90	17.85	23.80
7 1/2	3.19	4.78	6.36	7.96	9.57	12.75	19.13	25.50
8	3.40	5.10	6.80	8.50	10.20	13.60	20.40	27.20
8 1/2	3.61	5.42	7.22	9.03	10.84	14.44	21.68	28.90
9	3.82	5.74	7.65	9.56	11.48	15.30	22.96	30.60
9 1/2	4.04	6.06	8.08	10.10	12.44	16.16	24.23	32.20
10	4.25	6.38	8.50	10.62	12.75	17.00	25.50	34.00
10 1/2	4.46	6.70	8.92	11.16	13.39	17.85	26.78	35.10
11	4.68	7.02	9.34	11.68	14.03	18.70	28.09	37.40
11 1/2	4.90	7.34	9.76	12.22	14.66	19.55	29.35	39.10
12	5.10	7.66	10.20	12.70	15.30	20.40	30.60	40.80

Weights of Iron and Steel

Pounds Per Square Foot

U. S. Standard Gauges—½ Inch and Less

Thickness		Weight per Square Foot, Pounds		Thickness		Weight per Square Foot, Pounds	
Gauge No.	Decimals of an Inch	Iron	Steel	Gauge No.	Decimals of an Inch	Iron	Steel
7-0's	0.5	20.00	20.4	14	.078125	3.125	3.1875
6-0's	.46875	18.75	19.125	15	.0703125	2.8125	2.86875
5-0's	.4375	17.50	17.85	16	.0625	2.5	2.55
0000	.40625	16.25	16.575	17	.05625	2.25	2.295
000	.375	15.	15.30	18	.05	2.	2.04
00	.34375	13.75	14.025	19	.04375	1.75	1.785
0	.3125	12.50	12.75	20	.0375	1.50	1.53
1	.28125	11.25	11.475	21	.034375	1.375	1.4025
2	.265625	10.625	10.8375	22	.03125	1.25	1.275
3	.25	10.	10.2	23	.028125	1.125	1.1475
4	.234375	9.375	9.5625	24	.025	1.	1.02
5	.21875	8.75	8.925	25	.021875	.865	.8925
6	.203125	8.125	8.2875	26	.01875	.75	.765
7	.1875	7.5	7.65	27	.0171875	.6875	.70125
8	.171875	6.875	7.0125	28	.015625	.625	.6375
9	.15625	6.25	6.375	29	.0140625	.5625	.57375
10	.140625	5.625	5.7375	30	.0125	.5	.51
11	.125	5.	5.1	31	.010985	.4375	.44625
12	.109375	4.375	4.4625	32	.01045625	.40625	.414375
13	.09375	3.75	3.825	33	.009375	.375	.3825

Fractions of an Inch—Over ½ Inch Thick

Thickness, Inches		Weight per Square Foot, Pounds		Thickness, Inches		Weight per Square Foot, Pounds	
Fraction	Decimal	Iron	Steel	Fraction	Decimal	Iron	Steel
9/16	.5625	22.73	23.5	1 1/8	1.125	45.	46.
5/8	.625	25.26	26.	1 1/4	1.25	50.	51.
11/16	.6875	27.79	28.5	1 3/8	1.375	55.	56.1
3/4	.75	30.31	31.	1 1/2	1.5	60.63	61.2
13/16	.8125	32.84	33.5	1 5/8	1.625	65.68	66.3
7/8	.875	35.37	36.	1 3/4	1.75	70.73	71.4
15/16	.9375	37.89	38.5	1 7/8	1.875	75.	76.
1	1.	40.42	41.	2	2.	80.83	81

Weights of Materials

Pounds, Avoirdupois

Earths and Minerals	Cu. Ft.
Asphaltum	87.3
Basalt	181
Chalk	156
Clay, Potter's, Dry	119
Clay, Dry in Lump	63
Earth, Common Loam, Dry, Loose	76
Earth, Common Loam, Dry, Shaken	87
Earth, Common Loam, Moist, Loose	67
Earth, Common Loam, Moist, Shaken	82
Earth, Common Loam, as Mud	108
Feldspar	166
Gneiss, Common	168
Gneiss, Loose Piles	96
Granite, Solid	170
Gravel	117
Gypsum, Ground, Loose	56
Gypsum in Irregular Lumps	82
Gypsum, Shaken	64
Hornblende	203
Limestone, Piled	96
Limestone, Solid	168
Petroleum	54.8
Porphyry	170
Quartz, Ground Loose	90
Quartz, Shaken	105
Quartz, Solid	165
Sand, Coarse	117
Sand, Fine	100
Sandstone, Piled	86
Sandstone, Solid	151
Slate	175
Sulphur	125
Turf	25

Metals	Cu. In.
Aluminum	0.090
Antimony	.244
Arsenic	.208
Brass, Cast	.282
Brass, Rolled	.300
Bronze	.315
Copper, Pure	.318
Copper, Rolled	.321
Gold, Pure	.697
Gold, 20 Carat	.568
Iron, Cast	.261
Iron, Pure	.281
Iron, Wrought	.282
Lead, Hammered	.412
Lead, Pure	.410
Manganese	.290
Platinum, Pure	.706
Platinum, Rolled	.798
Spelter	.253
Steel, Cast	.286
Steel, Soft	.283

Metals—Contd.	Cu. In.
Tin	.264
Zinc, Cast	.248
Zinc, Rolled	.260

Woods	Cu. Ft.
Ashes, Damp	43
Ashes, Dry	38
Boxwood, Dry	60
Cherry, Dry	42
Chestnut, Dry	41
Cork	15.6
Ebony, Dry	76.1
Elm, Dry	35
Hemlock, Dry	25
Hickory, Dry	53
Lignum Vitae	83
Mahogany, Dry	53
Maple, Dry	49
Oak, Red	38
Oak, White	48
Pine, White	25
Pine, Yellow, Northern	34
Pine, Yellow, Southern	45
Spruce, Dry	25
Sycamore, Dry	37
Walnut, Black, Dry	38

Green Timbers weigh from 1-5 to 1-2 more than dry. Ordinarily seasoned about 1-6 more.

Miscellaneous Products	Cu. Ft.
Acid, Acetic	66.4
Acid, Muriatic	75
Acid, Sulphuric	115.2
Glass, Window	157
Gunpowder, Loose	56.1
Gunpowder, Shaken	62.4
Lard	59.3
Lime, Ground, Loose	53
Lime, Ground, Shaken	70
Lime, Quick, Solid	95
Mortar	103
Oil, Linseed	58.6
Pitch	71.7
Rosin	69
Rubber	58
Salt, Coarse	45
Salt, Fine	49
Snow, Fresh Fallen	12
Snow, Packed	50
Sugar	100
Tallow	58.6
Tar	62.4
Turpentine	54.3
Vinegar	67.4
Water, Pure	62.5
Water, Sea	64.1
Wine	62.3

Concrete Mixtures

Material Required for 1 Cu. Yd. of Concrete

Sand: 1.41 tons = 1 cu. yd. Stone: 1.2 tons = 1 cu. yd.

Mixture			Stone 2½ in. and Smaller; Dust Screened Out			Stone 2½ in. and Smaller; Small Stone Screened Out			Gravel ¾ in. and Smaller		
Cement, Parts	Sand, Parts	Stone, Parts	Cement, Barrels	Sand, Tons	Stone, Tons	Cement, Barrels	Sand, Tons	Stone, Tons	Cement, Barrels	Sand, Tons	Stone, Tons
1	1.0	2.0	2.63	.56	.96	2.72	.58	1.00	2.30	.49	.89
1	1.0	2.5	2.34	.61	1.07	2.41	.52	1.11	2.10	.45	.96
1	1.0	3.0	2.10	.45	1.15	2.16	.47	1.18	1.89	.41	1.03
1	1.0	3.5	1.88	.41	1.20	1.88	.41	1.26	1.71	.37	1.09
1	1.5	2.5	2.09	.68	.96	2.16	.69	.98	1.83	.59	.87
1	1.5	3.0	1.90	.61	1.04	1.96	.64	1.07	1.71	.55	.94
1	1.5	3.5	1.74	.56	1.12	1.79	.58	1.15	1.57	.51	1.00
1	1.5	4.0	1.61	.52	1.18	1.64	.54	1.20	1.46	.47	1.06
1	2.0	3.0	1.73	.75	.95	1.78	.76	.97	1.54	.66	.88
1	2.0	3.5	1.61	.69	1.02	1.66	.71	1.06	1.44	.62	.92
1	2.0	4.0	1.48	.64	1.08	1.53	.66	1.12	1.34	.58	.97
1	2.0	4.5	1.38	.59	1.14	1.43	.61	1.18	1.26	.54	1.03
1	2.0	5.0	1.29	.55	1.18	1.33	.65	1.24	1.17	.51	1.07
1	2.5	3.5	1.48	.79	.95	1.51	.82	.97	1.32	.71	.84
1	2.5	4.0	1.38	.75	1.01	1.42	.76	1.04	1.24	.66	.90
1	2.5	4.5	1.29	.69	1.06	1.33	.72	1.09	1.16	.62	.96
1	2.5	5.0	1.21	.65	1.11	1.26	.68	1.15	1.10	.59	1.00
1	2.5	6.0	1.07	.58	1.18	1.10	.58	1.24	.98	.52	1.07
1	3.0	4.0	1.28	.82	.94	1.32	.85	.96	1.15	.73	.87
1	3.0	4.5	1.20	.78	.98	1.24	.80	1.02	1.09	.71	.90
1	3.0	5.0	1.14	.73	1.04	1.17	.76	1.07	1.03	.66	.94
1	3.0	6.0	1.02	.66	1.12	1.02	.68	1.16	.92	.59	1.01
1	3.0	7.0	.92	.59	1.18	.94	.59	1.26	.84	.54	1.07
1	3.5	5.0	1.07	.80	.98	1.11	.83	1.02	.96	.71	.91
1	3.5	6.0	.97	.72	1.07	1.00	.75	1.11	.88	.65	.96
1	3.5	7.0	.89	.66	1.14	.91	.69	1.18	.80	.61	1.02
1	3.5	8.0	.82	.61	1.21	.81	.64	1.25	.73	.85	1.07
1	4.0	6.0	.92	.79	1.01	.95	.82	1.04	.83	.72	.92
1	4.0	7.0	.84	.72	1.08	.87	.75	1.12	.77	.66	.97
1	4.0	8.0	.78	.68	1.14	.81	.69	1.18	.71	.61	[illegible]
1	4.0	9.0	.73	.62	1.21	.75	.64	1.25	.65	.56	[illegible]

Wood Posts and Beams

When used as posts, columns or struts, in lengths not exceeding 12 feet, timber of usual kinds will safely carry, with a factor of 5, unit loads as follows:

Hemlock	500	pounds	per	square	inch
Oak	600	"	"	"	"
Yellow Pine	800	"	"	"	"
White Pine	500	"	"	"	"

For beams or girders the safe load can be determined from the following relation, using yellow pine as the standard:

Let W = Breaking load in pounds (uniformly distributed).
B = Breadth of beam in inches.
D = Depth of beam in inches.
L = Distance between supports in inches.

Then $W = 9000 \times B \times D^2 \div L$.

This gives the ultimate or breaking load, and should be divided by a factor of safety, depending on the conditions:

3 or 4 for roofs or floors.
5 or 6 for suddenly applied loads.

Since the equation above applies to yellow pine, the breaking load for other kinds of wood must be derived by taking:

$0.6 \times W$ for hemlock, or white pine.
$0.8 \times W$ for oak.

To obtain the net load, the weight of the beam itself must first be deducted from the breaking load, as follows:

25	pounds	per	cubic	foot	for	hemlock.
50	"	"	"	"	"	oak.
30	"	"	"	"	"	white pine.
35	"	"	"	"	"	yellow pine.

Beams will carry only half as much load concentrated at the middle as evenly distributed. Hence for concentrated loads, *make calculation* as above and take one-half the net uniformly *distributed load* as the proper concentrated load.

Example.—Loose bituminous coal, weighing 50 pounds per *ubic foot, is to be stored* in an overhead bunker 12 feet wide and *feet long, and the* maximum depth of the coal is to be 10 feet.

Wood Posts and Beams—Continued

How close should the floor joists be spaced if they are of 3×14-in. yellow pine? If 6-in. square yellow pine posts are to support the structure, how many will be required?

JOISTS—For the joists, B = 3, D = 14, L = 144.

Then for the breaking load
$W = 9000 \times 3 \times 14 \times 14 \div 144$
$= 36{,}700$ pounds.

And safe load, with factor of 4
$= 36{,}700 \div 4$
$= 9{,}175$ pounds.

Weight of each joist
= cubic feet × 35
$= (3 \times 14 \div 144) \times 12 \times 35$
= 122.5, or 125 pounds nearly.

Net allowable load per joist
= 9,175—125
= 9,050 pounds.

Maximum weight of coal in bunker
$= 12 \times 60 \times 10 \times 50$
= 360,000 pounds.

Number of joists required
$= 360{,}000 \div 9{,}050$
= 39.78, or 40 joists.

Spacing of joists on centers
$= 60 \div 40$
= 1.5 ft., or 18 in.

POSTS—Maximum weight of coal	360,000	pounds
Approximate weight of bunker	50,000	"
Total weight to be supported	410,000	"

Safe load for a 6-in. yellow pine post
$= 6 \times 6 \times 800$
= 28,800 pounds.

Number of such posts required
$= 410{,}000 \div 28{,}800$
= 14.23, or 15 posts.

Actually, 16 or more posts would likely be used.

Board Measure

Number of Feet, Board Measure, per Lineal Foot for Various Widths and Thicknesses.

Width of Board, In.	Thickness of Board, Inches												
	1	1½	2	2½	3	3½	4	5	6	7	8	9	10
3	0.250	0.375	0.500	0.625	0.750	....	....	....	....	....	....	....	....
3½	.292	.438	.583	.729	.875	1.021	....	....	....	....	....	....	....
4	.333	.500	.667	.833	1.000	1.167	1.333	....	....	....	....	....	....
4½	.375	.563	.750	.938	1.125	1.313	1.500	....	....	....	....	....	....
5	.417	.625	.833	1.042	1.250	1.457	1.666	2.083	....	....	....	....	....
6	.500	.750	1.000	1.250	1.500	1.750	2.000	2.500	3.000	....	....	....	....
7	.583	.875	1.167	1.458	1.750	2.042	2.333	2.917	3.500	4.083	....	....	....
8	.667	1.000	1.333	1.667	2.000	2.333	2.667	3.333	4.000	4.667	5.333	....	....
9	.750	1.125	1.500	1.875	2.250	2.625	3.000	3.750	4.500	5.250	6.000	6.750	....
10	.833	1.250	1.667	2.083	2.500	2.917	3.333	4.167	5.000	5.833	6.667	7.500	8.333
11	.917	1.375	1.833	2.292	2.750	3.208	3.667	4.583	5.500	6.417	7.333	8.250	9.167
12	1.000	1.500	2.000	2.500	3.000	3.500	4.000	5.000	6.000	7.000	8.000	9.000	10.00
13	1.083	1.625	2.167	2.708	3.250	3.792	4.333	5.417	6.500	7.583	8.667	9.750	10.83
14	1.167	1.750	2.333	2.917	3.500	4.083	4.667	5.833	7.000	8.167	9.333	10.50	11.67
15	1.250	1.875	2.500	3.125	3.750	4.375	5.000	6.250	7.500	8.750	10.00	11.25	12.50
16	1.333	2.000	2.667	3.333	4.000	4.667	5.333	6.667	8.000	9.333	10.67	12.00	13.33
18	1.500	2.250	3.000	3.750	4.500	5.250	6.000	7.500	9.000	10.50	12.00	13.50	15.00
20	1.667	2.500	3.333	4.167	5.000	5.833	6.667	8.333	10.00	11.67	13.33	15.00	16.67

Boiling Temperatures

At Atmospheric Pressure

Degrees Fahrenheit and Centigrade

	Fahr. Degrees	Cent. Degrees		Fahr. Degrees	Cent. Degrees
Ammonia	140	60	Nitric Acid	248	120
Wood Alcohol	150	66	Turpentine	315	139
Grain Alcohol	173	79	Phosphorus	554	272
Benzine	176	80	Sulphur	570	281
Water	212	100	Sulphuric Acid	590	292
Sea Water	213	101	Linseed Oil	597	296
Saturated Brine	226	108	Mercury	676	340

Melting Temperatures

	Fahr. Degrees	Cent. Degrees		Fahr. Degrees	Cent. Degrees
Mercury	—39	—39	Aluminum	1213	657
Turpentine	14	—10	Bronze	1652	900
Ice	32	0	Silver	1751	955
Nitroglycerine	45	7	Glass	1832	1000
Tallow	92	33	Brass	1859	1015
Phosphorus	112	44	Gold	1947	1064
Wax	150	66	Copper	1949	1065
Sulphur	239	115	Iron, White Pig	1967	1075
Tin	446	230	Iron, Gray Pig	2192	1200
Bismuth	507	264	Steel	2507	1375
Lead	621	327	Nickel	2732	1500
Zinc	787	419	Manganese	3452	1900
Antimony	815	435	Platinum	3452	1900

Fusible Metals—Melting Temperatures

Alloy			Fahr. Degrees	Cent. Degrees	Alloy			Fahr. Degrees	Cent. Degrees
Tin	Lead	Bismuth			Tin	Lead	Bismuth		
1	1	2	200	93	....	1	1	257	125
1	1	4	201	94	1	....	1	286	141
3	5	8	202	94	3	2	......	334	150
3	....	5	202	94	2	....	1	336	151
5	3	8	208	98	2	1	......	360	164
2	3	5	212	100	3	....	1	392	182
3	1	5	212	100	1	1	......	466	223
4	1	5	240	116	1	2	......	475	22[illegible]

Total Coal Contents of Seams of Different Thicknesses

Short Tons

Density of Coal Assumed as 1.28; or
25 Cubic Feet per Ton of 2,000 Pounds

Height of Coal, Inches	Tons of Coal, per Acre	Tons per Square Foot Undercut	Depth of Undercut		
			5 Ft.	6 Ft.	7 Ft.
			Tons per Lineal Foot of Face		
24	3485	0.08	0.40	0.48	0.56
28	4070	.09	.47	.56	.65
32	4645	.11	.54	.64	.75
36	5225	.12	.60	.72	.84
40	5810	.133	.67	.80	.93
44	6390	.15	.73	.88	1.02
48	6970	.16	.80	.96	1.12
54	7840	.18	.90	1.08	1.26
60	8715	.20	1.00	1.20	1.40
66	9580	.22	1.10	1.32	1.54
72	10455	.24	1.20	1.44	1.68
78	11320	.26	1.30	1.56	1.82
84	12210	.28	1.40	1.68	1.96
90	13070	.30	1.50	1.80	2.10
96	13940	.32	1.60	1.92	2.24
100	14525	.333	1.67	2.00	2.33
104	15100	.347	1.73	2.08	2.42
108	15680	.36	1.80	2.16	2.52
112	16260	.373	1.87	2.24	2.61
116	16845	.387	1.93	2.32	2.70
120	17425	.40	2.00	2.40	2.80
126	*18295*	.42	2.10	2.52	2.94
132	*19165*	.44	2.20	2.64	3.08
138	*20040*	.46	2.30	2.76	3.22
144	*20900*	.48	2.40	2.88	3.36

Coal Fields of the United States

The coal areas of the United States are divided, for the sake of convenience, into two great divisions—anthracite and bituminous.

The areas in which anthracite is produced are confined almost exclusively to the eastern part of Pennsylvania. These fields, which are included in the counties of Susquehanna, Lackawanna, Luzerne, Carbon, Schuylkill, Columbia, Northumberland, Dauphin and Sullivan, underlie an area of about 480 square miles. Two small areas in the Rocky Mountain region, Gunnisson County, Colo., and Santa Fe County, N. M., have yielded a good quality of anthracite, though the production from these districts had never amounted to as much as 100,000 tons in any one year. Bristol, R. I., and Plymouth, Mass., have yielded some coal classed as anthracite.

The bituminous and lignite fields are scattered widely over the United States and include an area of something over 496,000 square miles. The lastest classification of these coal areas divides them into six provinces, as follows:

(1) The Eastern province: This includes all of the bituminous areas of the Appalachian region; the Atlantic coast region which includes the Triassic fields near Richmond, the Deep River and Dan River fields of North Carolina and the anthracite region of Pennsylvania.

(2) The Gulf province: This includes the lignite fields of Alabama, Mississippi, Louisiana, Arkansas and Texas.

(3) The Interior province: This includes all the bituminous areas of the Mississippi valley region and the coal fields of Michigan. This province is sub-divided into the eastern region, which embraces the coal fields of Illinois, Indiana and Western Kentucky; the western region, which includes the fields of Iowa, Missouri, Nebraska, Kansas, Arkansas and Oklahoma; and the southwestern region, which includes the coal fields of Texas. The Michigan fields are designated as the northern region of the Interior province.

(4) The Northern or Great Plains province: This includes the lignite areas of N. Dakota and S. Dakota, the bituminous and sub-bituminous areas of northwestern Wyoming and of northern and eastern Montana.

(5) The Rocky Mountain province: This includes the coal fields of the mountainous districts of Montana and Wyoming and all the coal fields of Utah, Colorado and New Mexico.

(6) The Pacific Coast province: This includes all of the coal fields of California, Oregon and Washington.

Coal Production in the United States

From the Earliest Times to the Close of 1918

So far as known the first mention of the occurrence of coal in the United States is made in the journal of Father Hennepin, a French Jesuit Missionary, who in 1679, recorded the site of a "cole mine" on the Illinois River, near the present city of Ottawa, Ill. The first actual mining of coal was in the Richmond Basin, Virginia, about 1750, although the first records of production from these mines are for the year 1822, when, according to one authority, 54,000 tons were mined. Ohio probably ranks second in priority of production, as coal was discovered there in 1755, though the records of production date back only to 1838.

The mining of anthracite in Pennsylvania began about 1790 and it is said that in 1807, 55 tons were shipped to Columbia, Pa. Reports of the anthracite coal trade are usually begun with the year 1820, when 365 long tons were shipped to Philadelphia from the Lehigh region. Prior to this, however, in 1814, a shipment of 22 tons was made from Carbondale to Philadelphia, and production may historically be considered as dating from that year.

Production and use of coal, both bituminous and anthracite, have continued from those early days at a constantly increasing rate as industry has created the market. The annual production, bituminous and anthracite combined, reached a hundred million tons in 1882, two hundred millions in 1897, three hundred in 1902, four hundred in 1906, five hundred in 1910 and six hundred millions nearly, in 1916. Then the war years of special effort yielded more than 650 million tons in 1917, and nearly 700 millions in 1918.

Coal Production for 1918

Early Estimate

For 1917 Production, see next page

State	Production 1918 (Estimate) Short Tons	Increase over 1917, Short Tons	Decrease from 1917 Short Tons	Percentage 1918 over 1917 In-crease	Percentage 1918 over 1917 De-crease
Alabama	21,280,000	1,212,000	....	6.0	......
Arkansas	2,228,000	84,000	....	4.0	......
Colorado	12,485,000	2,000	....	0.0	......
Georgia	101,000	....	18,000	......	15.0
Illinois	91,263,000	5,064,000	....	6.0	......
Indiana	27,325,000	785,000	....	3.0	......
Iowa	8,240,000	....	725,000	......	8.0
Kansas	7,392,000	107,000	....	1.5	......
Kentucky	29,690,000	1,882,000	....	7.0	......
Maryland	4,759,000	13,000	....	0.3	......
Michigan	1,385,000	10,000	....	0.7	......
Missouri	5,605,000	....	56,000	......	1.0
Montana	4,276,000	49,000	....	1.0	......
New Mexico	4,241,000	241,000	....	6.0	......
North Dakota	813,000	23,000	....	3.0	......
Ohio	46,464,000	5,715,000	....	14.0	......
Oklahoma	4,785,000	318,000	....	9.0	......
Pennsylvania	183,712,000	11,264,000	....	6.5	......
Tennessee	6,916,000	722,000	....	12.0	......
Texas	2,260,000	....	96,000	......	4.0
Utah	5,535,000	1,410,000	....	34.0	......
Virginia	10,100,000	13,000	....	0.1	......
Washington	4,056,000	46,000	....	1.0	......
West Virginia	91,350,000	4,908,000	....	6.0	......
Wyoming	9,600,000	1,024,000	....	12.0	......
Alaska, California, Idaho, Oregon, South Dakota	122,000	25,000	....	......	......
Total Bit.	585,883,000	34,092,000	....	6.2	......
Penna. Anth.	99,473,000	....	138,000	......	0.1
Grand Total	685,356,000	33,954,000	....	5.2	......

Men Employed and Days Worked

To Yield the Coal Production of 1917

State	Total Production Short Tons	Number of Men			Average Number of Days Worked
		Under-ground	On Surface	Total	
Alabama	20,068,074	22,925	5,461	28,386	273
Alaska	53,955	*	*	*	*
Arkansas	2,143,579	3,135	863	3,998	187
Cal. & Idaho	6,423	11	6	17	173
Colorado	12,483,336	11,285	2,946	14,231	263
Georgia	119,028	205	76	281	269
Illinois	86,199,387	75,085	9,005	84,090	243
Indiana	26,539,329	22,664	3,864	26,528	221
Iowa	8,965,830	12,672	1,594	14,266	251
Kansas	7,184,975	8,816	1,864	10,680	216
Kentucky	27,807,971	28,162	6,764	34,926	214
Maryland	4,745,924	4,696	1,223	5,919	254
Michigan	1,374,805	2,154	252	2,406	254
Missouri	5,670,549	7,680	1,988	9,668	240
Montana	4,226,689	3,338	811	4,149	268
New Mexico	4,000,527	3,191	935	4,126	321
North Dakota	790,548	619	202	821	255
Ohio	40,748,734	38,569	6,940	45,509	210
Oklahoma	4,386,844	7,017	1,478	8,495	211
Oregon	28,327	77	27	104	251
Penna. (Bit.)	172,448,142	143,687	30,281	173,968	261
South Dakota	8,042	34	0	34	154
Tennessee	6,194,221	8,053	2,368	10,421	241
Texas	2,355,815	3,683	692	4,375	263
Utah	4,125,230	2,569	916	3,485	219
Virginia	10,087,091	8,607	2,561	11,168	273
Washington	4,009,902	4,072	1,240	5,312	271
West Virginia	86,441,667	69,155	19,267	88,422	225
Wyoming	8,575,619	6,024	1,334	7,358	246
Total Bit	551,790,563	498,185	104,958	603,143	243
Penna. Anth.	99,611,811	109,989	44,185	154,174	285
Grand Total	651,402,374	680,174	149,143	757,317	251

*Not available.

Production of Coke

In the United States, 1917 and 1918

(Early Estimates, 1918)

State	Production Short Tons		Percentage 1918 over 1917	
	1917	1918	Increase	Decrease
Beehive Coke				
Alabama	2,151,828	2,566,000	19.2	....
Colorado	1,112,449	771,000	....	30.7
Georgia	39,589	24,000	....	40.6
Kentucky	331,532	329,000	....	0.9
New Mexico	577,679	588,000	1.9	....
Ohio	147,826	132,000	....	10.6
Oklahoma	....	45,000	....	....
Pennsylvania	23,816,420	21,031,000	....	11.7
Tennessee	376,080	419,000	11.4	....
Virginia	1,304,230	1,255,000	....	3.8
West Virginia	2,838,728	2,634,000	....	7.2
Utah and Wash.	471,187	612,000	29.9	....
Total	33,167,548	30,406,000	....	8.3
By-Product Coke				
Alabama	2,740,761	2,676,000	....	2.4
Illinois	2,289,833	2,278,000	....	0.6
Indiana	3,540,718	3,870,000	9.3	....
Kentucky	531,539	522,000	....	1.8
Maryland	518,810	477,000	....	8.1
Massachusetts	595,113	542,000	....	8.9
Minnesota	490,272	742,000	51.4	....
New York	993,184	1,086,000	9.3	....
Ohio	3,546,476	5,283,000	49.0	....
Pennsylvania	4,095,605	4,691,000	14.5	....
Tennessee	35,246	121,000	243.7	....
Washington	26,346	30,000	14.9	....
West Virginia	511,033	612,000	19.7	....
Colorado, Michigan, Missouri, New Jersey, Wisconsin	2,524,344	3,334,000	32.1	....
Total	22,439,280	26,264,000	17.0	....
Grand Total	55,606,828	56,670,000	1.9	....

Percentages of Grand Totals

Beehive: *1917—59.6%* By-Product: 1917—40.4%
1918—53.6% 1918—46.4%

Mining Machines Used in Bituminous Coal Production

By States for the Year 1916

State	Number of Mining Machines in Use	Coal Mined by Machines, Short Tons	Total Production Short Tons	Percentage Mined by Machines
Alabama	320	5,802,150	18,086,197	32.1
Arkansas	20	224,245	1,994,915	11.2
Colorado	305	3,342,345	10,484,237	31.9
Illinois	1,938	40,791,408	66,195,336	61.7
Indiana	661	11,367,758	20,093,528	56.6
Iowa	56	636,892	7,260,800	8.8
Kansas	6	37,897	6,881,455	.6
Kentucky	1,528	21,441,700	25,393,997	84.4
Maryland	16	221,609	4,460,046	5.0
Michigan	104	1,044,583	1,180,360	88.5
Missouri	93	947,811	4,742,146	20.0
Montana	103	2,024,799	3,632,527	55.7
New Mexico	51	510,219	3,793,011	13.5
North Dakota	13	218,276	634,912	34.4
Ohio	1,604	31,669,049	34,728,219	91.1
Oklahoma	167	1,258,022	3,608,011	34.8
Pennsylvania	5,768	94,391,391	170,295,424	55.4
Tennessee	213	1,517,426	6,137,449	24.7
Texas	10	19,000	1,987,503	1.0
Utah	78	2,050,405	3,567,428	57.5
Virginia	194	6,011,262	9,707,474	61.9
Washington	55	277,236	3,038,588	9.1
West Virginia	2,702	54,408,511	86,460,127	62.9
Wyoming	192	3,477,081	7,910,647	44.0
Other States	....	400	71,791	.6
Total	16,197	283,691,475	502,519,682	*56.4

*Average percentage.

In the United States, 1891-1916

Year	Number of Machines in Use	Coal Mined by Machines, Short Tons	Year	Number of Machines in Use	Coal Mined by Machines, Short Tons
1891	*545*	6,211,732	1906	10,212	118,847,527
1896	*1,446*	16,424,932	1911	13,829	178,158,236
1901	*4,341*	57,843,335	1916	16,197	283,691,475

Disposal of Coal Produced

In the United States, 1916

State	Loaded at Mines for Shipment, Short Tons	Sold to Local Trade and Used by Employees Short Tons	Used at Mines for Steam and Heat, Short Tons	Made into Coke at Mines, Short Tons
Alabama	14,422,356	390,682	587,211	2,685,948
Alaska	7,913	5,098	62	....
Arkansas	1,881,105	44,254	69,556	....
Cal. and Idaho	1,593	4,647	1,000	....
Colorado	8,057,820	396,376	271,484	1,758,557
Georgia	76,954	1,672	7,200	87,728
Illinois	61,486,342	3,086,157	1,622,837	....
Indiana	18,839,568	790,345	463,615	....
Iowa	6,521,770	591,717	147,313	....
Kansas	6,577,064	145,053	159,338	....
Kentucky	23,473,421	783,268	484,741	652,567
Maryland	4,320,720	74,113	65,213	....
Michigan	1,097,107	51,770	31,483	....
Missouri	4,219,414	435,868	86,864	....
Montana	3,350,665	142,130	139,732	....
New Mexico	2,873,313	50,421	25,194	844,083
North Dakota	440,752	173,936	20,224	....
Ohio	31,995,913	2,123,678	607,908	720
Oklahoma	3,395,363	34,000	178,648	....
Oregon	28,373	7,482	6,737	....
Penna. (Bit.)	123,181,649	4,212,186	3,375,483	39,526,106
South Dakota	891	7,995	....	....
Tennessee	5,266,733	99,289	174,093	597,334
Texas	1,939,947	17,670	29,886	....
Utah	2,686,880	65,260	78,435	736,853
Virginia	7,513,641	156,730	113,376	1,923,727
Washington	2,701,031	75,954	124,740	136,863
West Virginia	79,760,681	1,768,827	1,171,205	3,759,414
Wyoming	7,547,706	96,055	266,886	....
Total Bit.	423,666,685	15,832,633	10,310,464	52,709,900
Penna. Anth.	75,601,526	2,216,087	9,760,880	....
Grand Total	499,268,211	18,048,720	20,071,344	52,709,900
Percentage of: Total Production				
Bituminous	84.3	3.2	2.0	10.5
Penna. Anth.	86.3	2.5	11.2	....

Copper Fields of the United States

There are several methods of classifying copper deposits; namely, according to the geologic period of deposit, the geologic occurrence, and the geographic distribution.

According to Geologic Age

1. Pre-Cambrian, the larger producers of which have been the Lake Superior district of Michigan, the Jerome of Arizona and the Encampment of Wyoming. The deposits of this age yield about one-third of the total output of the country.
2. Paleozoic, the most important producers of which are the Ducktown district of Tennessee, the Great Gossan lead of Virginia and North Carolina, the Virgilina district, and the Ely of Vermont. These are usually classed as the Appalachian deposits.
3. Mesozoic, consisting chiefly of the Shasta district and the "foothills" of California, together with numerous districts of Idaho, eastern Washington, western Nevada and Alaska. The deposits of this age yield about one-fourth of the country's output.
4. Tertiary, largely found in Montana, Arizona, New Mexico and Utah. This is considered the most important of the epochs of copper deposition, it giving almost half the output of this country.

According to Occurrence

1. Lenticular replacements in schistose and igneous rocks, found in Arizona and California, and to a small extent in the Appalachian region.
2. Native copper in volcanic rocks, which is the kind chiefly found in the Lake Superior district of Michigan.
3. Replacement deposits in sedimentary rocks, usually found in Arizona, Nevada, Utah and Alaska.
4. Disseminated deposits, occurring chiefly in Utah, Nevada and Arizona; not of very high grade, but usually cheap to mine.
5. Fissure-vein deposits, which are the chief sources of copper and are mostly found at Butte, Montana.
6. Disseminated deposits of sedimentary rocks, found mostly in Texas, New Mexico and Arizona.

Geographic Distribution

Copper is present in some form or other in almost every *State in the Union.* According to smelter returns, the leading *States are Arizona,* Montana and Michigan.

Although our copper industry is still young, the United *States is, at present,* supplying more than half of the world's *production.*

Copper Production

In the United States, 1916 and 1917

By States

State	Production, Pounds		Percentage, 1917 over 1916	
	1916	1917	Increase	Decrease
Alaska	113,823,064	84,759,086	....	25.6
Arizona	694,847,307	719,035,514	3.5	....
California	43,400,876	44,933,846	3.5	....
Colorado	9,536,193	10,054,951	5.4	....
Georgia	803,699	930,691	15.8	....
Idaho	7,248,794	6,446,224	....	11.1
Maine	....	34,872	....	....
Maryland	126,965	291,501	129.6	....
Michigan	269,794,531	268,508,091	....	.5
Missouri	377,575	407,141	7.8	....
Montana	352,139,768	276,225,977	....	21.5
Nevada	100,816,724	115,028,161	14.1	....
New Jersey	4,115	....	....	....
New Mexico	79,863,439	107,593,615	34.7	....
North Carolina	5,961	125,004	500.8	....
Oregon	2,433,567	1,105,097	....	54.6
Pennsylvania	904	115,000	....	....
South Carolina	....	210,000	....	....
Tennessee	14,556,278	16,093,757	10.6	....
Texas	86,463	2,061,129	228.4	....
Utah	232,335,950	227,840,447	....	1.9
Vermont	324,400	102,522	....	68.4
Virginia	1,066,143	146,912	....	86.2
Washington	2,473,481	2,051,416	....	17.1
Wyoming	1,784,351	2,019,767	13.2	....
Total	1,927,850,548	1,886,120,721	....	2.17

Imports and Exports

Of Copper in all Forms, 1916 and 1917

	1916, Pounds	1917, Pounds	Percentage Increase 1917 over 1916
Imports	462,335,980	556,420,297	20.4
Exports	789,791,254	1,131,872,927	43.3

Copper Production and Disposal

In the United States, 1907-1917

Domestic Production

Year	Refined Copper, Primary, Pounds	Secondary Copper, Pounds	Smelter Production, Domestic Ores, Pounds
1907	1,032,500,000	....	868,900,000
1908	1,137,900,000	....	942,500,000
1909	1,391,000,000	....	1,092,900,000
1910	1,422,000,000	....	1,080,000,000
1911	1,433,800,000	214,000,000	1,097,000,000
1912	1,568,100,000	275,000,000	1,243,000,000
1913	1,615,000,000	273,000,000	1,224,000,000
1914	1,533,700,000	255,700,000	1,150,000,000
1915	1,634,200,000	392,200,000	1,388,000,000
1916	2,259,000,000	700,000,000	1,928,000,000
1917	2,428,000,000	....	1,886,000,000

Imports, Exports and Consumption

Year	Imports, Pounds	Exports of Metallic Copper, Pounds	Domestic Consumption, Pounds
1907	252,600,000	508,900,000	487,700,000
1908	218,700,000	661,800,000	479,900,000
1909	321,800,000	682,800,000	688,500,000
1910	344,000,000	708,000,000	732,000,000
1911	334,600,000	786,500,000	681,700,000
1912	410,000,000	775,000,000	755,900,000
1913	408,700,000	926,000,000	812,000,000
1914	306,000,000	840,000,000	620,000,000
1915	315,600,000	681,900,000	1,043,000,000
1916	462,000,000	784,000,000	1,430,000,000
1917	556,000,000	1,126,000,000	1,316,000,000

Average Yearly Prices

Year	Per Pound	Year	Per Pound	Year	Per Pound	Year	Per Pound
1907	$0.200	1910	$0.127	1913	$0.155	1916	$0.246
1908	.132	1911	.125	1914	.133	1917	.273
1909	.130	1912	.165	1915	.175	1918	.....

Iron Mining in the United States

The classification of the iron deposits is usually made by dividing the country into six geographic districts, namely:

1. Northeastern District—Massachusetts, Connecticut, New York, New Jersey, Pennsylvania and Ohio.
2. Southeastern District—Maryland, Virginia, West Virginia, Kentucky, Tennessee, North Carolina, Georgia and Alabama.
3. Lake Superior District—Michigan, Wisconsin and Minnesota.
4. Mississippi Valley District—Iowa, Mississippi, Missouri, Arkansas and Texas.
5. Rocky Mountain District—Idaho, Montana, Wyoming, Colorado, New Mexico, Utah and Nevada.
6. Pacific Slope District—Washington and California.

The Lake Superior district is by far the most important, producing nearly 85 percent of the total output of the United States.

Classes of Ore

Each of the above districts can be further subdivided into mining districts, and the ores classified with regard to variety and distribution of the deposits:

1. Hematite—Known locally as red hematite, specular ore, gray ore, fossile ore, etc. This is the most important variety, constituting more than 90 percent of the United States' production.
2. Brown ore—Known also as brown hematite, bog ore, limonite, etc. This variety usually comes from the Appalachian States and constitutes less than 3 percent of the total.
3. Magnetite—Usually called magnetic iron ore. Comes mostly from the Northeastern district, except Ohio, and constitutes less than 4 percent of the total.
4. Iron carbonate—Known locally as spathic iron ore, kidney ore, black band ore, etc. This is the least significant of the ores and comes principally from Ohio.

The Iron Ranges

The Lake Superior district includes the Vermilion, Mesabi, Cuyuna, Gogebic, Marquette and Menominee ranges. In addition to these there are several iron ore districts on the Canada side of the Great Lakes, the principal ones being the Michipicoten, Animikie, Matawin and the Atikokan ranges.

The Mesabi range, within the Superior district, produced *more than half* of the entire output for the United States *during the year* 1917.

The iron mined in the United States amounts to nea *double that* mined in any other country.

Iron Ore Production

In the United States, 1916 and 1917

By States

In Order of their Producing Rank, 1917

State	Production Long Tons		Percentage 1917 over 1916	
	1916	1917	Increase	Decrease
Minnesota	44,585,422	44,595,232	0.02	....
Michigan	18,071,016	17,868,601	....	1.1
Alabama	6,747,901	7,037,707	4.3	....
New York	1,342,507	1,304,317	....	2.8
Wisconsin	1,304,518	1,202,235	....	7.8
Pennsylvania	559,431	546,700	....	2.3
Wyoming	545,774	543,846	....	0.4
Tennessee	455,834	508,529	11.6	....
New Jersey	493,004	489,943	....	0.6
Virginia	440,492	469,903	6.7	....
New Mexico	157,779	237,221	50.4	....
Georgia	256,949	226,630	....	11.8
North Carolina	64,306	90,997	41.5	....
Utah	45,514	48,058	5.6	....
Missouri	34,914	38,908	11.4	....
Iowa	11,351	22,612	99.2	....
Maryland	4,455	11,830	165.5	....
West Virginia	3,605	4,632	28.5	....
California	3,000	2,207	....	26.4
Nevada	9,910	1,010	....	89.8
Ohio	1,800	0	....	100.0
Other States*	28,190	37,733	33.8	....
Total	75,167,672	75,288,851	0.16	....

*1916—Colorado, Connecticut, Massachusetts.

*1917—Arkansas, Colorado, Connecticut, Massachusetts, Montana.

Iron Ore Production

In the United States, 1916 and 1917

By Districts

In Order of their Producing Rank

District	Production, Long Tons		Percentage 1917 over 1916	
	1916	1917	Increase	Decrease
Lake Superior.....	63,735,088	63,481,321	....	0.39
Birmingham......	5,976,918	6,187,073	3.53	....
Adirondack........	1,077,638	1,100,001	....	1.81
Chattanooga......	836,623	821,485	2.07	....
Northern New Jersey and Southeastern New York	683,150	642,232	....	5.99
Other Districts....	2,859,155	3,056,739	6.91	....
Total..........	75,167,672	75,288,851	0.16	....

By Ranges in Lake Superior District

In Order of their Producing Rank, 1917

Range	1916 Long Tons	1917 Long Tons	Percentage 1917 over 1916	
			Increase	Decrease
Mesabi...........	41,325,341	41,127,323	....	0.48
Gogebic..........	7,707,101	7,881,232	2.26	....
Menominee.......	6,649,578	6,366,483	....	4.26
Marquette........	4,792,987	4,638,374	....	3.22
Cuyuna..........	1,555,641	1,986,608	27.7	....
Vermilion.........	1,704,440	1,481,301	....	13.09
Total..........	63,735,088	63,481,321	....	0.4

Largest Iron Ore Mines

Eleven mines in the United States produced more than 1,000,000 tons of iron ore each in 1917. First place was held by the Hull-Rust mine at Hibbing, Minn.; second place by the Red Mountain group near Bessemer, Ala.; third place by the Mahoning mine at Hibbing, Minn.; fourth place by the Fayal mine at Eveleth, Minn. The production of these mines was respectively, 6,468,483, 2,955,022, 2,525,145 and 2,022,816 tons.

Decimals of a Foot, in Inches and Decimals

If common fractions of inches are wanted, convert the fractional parts of inches in this table by use of table on following page.

Foot	Inches	Foot	Inches	Foot	Inches
0.01	0.12	0.36	4.32	0.71	8.52
.02	.24	.37	4.44	.72	8.64
.03	.36	.38	4.56	.73	8.76
.04	.48	.39	4.68	.74	8.88
.05	.6	.40	4.8	.75	9.
.06	.72	.41	4.92	.76	9.12
.07	.84	.42	5.04	.77	9.24
.08	.96	.43	5.16	.78	9.36
.09	1.08	.44	5.28	.79	9.48
.10	1.2	.45	5.4	.80	9.6
.11	1.32	.46	5.52	.81	9.72
.12	1.44	.47	5.64	.82	9.84
.13	1.56	.48	5.76	.83	9.96
.14	1.68	.49	5.88	.84	10.08
.15	1.8	.50	6.	.85	10.2
.16	1.92	.51	6.12	.86	10.32
.17	2.04	.52	6.24	.87	10.44
.18	2.16	.53	6.36	.88	10.56
.19	2.28	.54	6.48	.89	10.68
.20	2.4	.55	6.6	.90	10.8
.21	2.52	.56	6.72	.91	10.92
.22	2.64	.57	6.84	.92	11.04
.23	2.76	.58	6.96	.93	11.16
.24	2.88	.59	7.08	.94	11.28
.25	3.	.60	7.2	.95	11.4
.26	3.12	.61	7.32	.96	11.52
.27	3.24	.62	7.44	.97	11.64
.28	3.36	.63	7.56	.98	11.76
.29	3.48	.64	7.68	.99	11.88
.30	3.6	.65	7.8	1.00	12.
.31	3.72	.66	7.92		
.32	3.84	.67	8.04		
.33	3.96	.68	8.16		
.34	4.08	.69	8.28		
.35	4.2	.70	8.4		

Decimal Equivalents of Common Binary Fractions

—By 64ths—

Common Fraction	Decimal	Common Fraction	Decimal
1/64	0.015625	33/64	0.515625
1/32......	.03125	17/32......	.53125
3/64	.046875	35/64	.546875
1/16............	.0625	9/16............	.5625
5/64	.078125	37/64	.578125
3/32......	.09375	19/32......	.59375
7/64	.109375	39/64	.609375
1/8...............	.125	5/8...............	.625
9/64	.140625	41/64	.640625
5/32......	.15625	21/32......	.65625
11/64	.171875	43/64	.671825
3/16............	.1875	11/16............	.6875
13/64	.203125	45/64	.703125
7/32......	.21875	23/32......	.71875
15/64	.234375	47/64	.734375
1/4...............	.25	3/4...............	.75
17/64	.265625	49/64	.765625
9/32......	.28125	25/32......	.78125
19/64	.296875	51/64	.796875
5/16............	.3125	13/16..........	.8125
21/64	.328125	53/64	.828125
11/32......	.34375	27/32......	.84375
23/64	.359375	55/64	.859375
3/8...............	.375	7/8...............	.875
25/64	.390625	57/64	.890625
13/32......	.40625	29/32......	.90625
27/64	.421875	59/64	.921875
7/16............	.4375	15/16............	.9375
29/64	.453125	61/64	.953125
15/32......	.46875	31/32......	.96875
31/64	.484375	63/64	.984375
1/2...............	.5	1...............	1.

Squares, Cubes, Square Roots, Cube Roots, Circumferences and Areas

From .1 to 120; by Tenths to 10

For Circles by Eighths, see pages 130 and 131.

Number or Diam.	Square	Cube	Square Root	Cube Root	Circle	
					Circum.	Area
.1	0.01	0.001	0.316	0.464	0.314	0.00785
.2	.04	.008	.447	.585	.628	.0314
.3	.09	.027	.548	.669	.942	.0707
.4	.16	.064	.633	.737	1.257	.126
.5	.25	.125	.707	.794	1.571	.196
.6	.36	.216	.775	.843	1.885	.283
.7	.49	.343	.837	.888	2.199	.385
.8	.64	.512	.894	.928	2.513	.503
.9	.81	.729	.949	.960	2.827	.636
1.	1.	1.	1.	1.	3.142	.785
.1	1.21	1.331	1.049	1.032	3.456	.950
.2	1.44	1.728	1.095	1.063	3.770	1.131
.3	1.69	2.197	1.140	1.091	4.084	1.327
.4	1.96	2.744	1.183	1.119	4.398	1.539
.5	2.25	3.375	1.225	1.145	4.712	1.767
.6	2.56	4.096	1.265	1.170	5.027	2.011
.7	2.89	4.913	1.304	1.193	5.341	2.270
.8	3.24	5.832	1.342	1.216	5.655	2.545
.9	3.61	6.859	1.378	1.239	5.970	2.835
2.	4.	8.	1.414	1.260	6.283	3.142
.1	4.41	9.261	1.449	1.281	6.597	3.464
.2	4.84	10.648	1.483	1.301	6.912	3.801
.3	5.29	12.167	1.517	1.320	7.226	4.155
.4	5.76	13.824	1.549	1.339	7.540	4.524
.5	6.25	15.625	1.581	1.357	7.854	4.909
.6	6.76	17.576	1.612	1.375	8.168	5.309
.7	7.29	19.683	1.643	1.392	8.482	5.726
.8	7.84	21.952	1.673	1.409	8.797	6.158
.9	8.41	24.389	1.703	1.426	9.111	6.605
3.	*9.*	*27.*	1.732	1.442	9.425	7.069
.1	*9.61*	*29.791*	1.761	1.458	9.739	7.548
.2	*10.24*	*32.768*	1.789	1.474	10.053	8.043
.3	*10.89*	*35.937*	1.817	1.489	10.367	8.553
.4	*11.56*	*39.304*	1.844	1.504	10.681	9.079

Squares, Cubes, Square Roots, Cube Roots, Circumferences and Areas

From .1 to 120; by Tenths to 10.

For Circles by Eighths, see pages 130 and 131.

Number or Diam.	Square	Cube	Square Root	Cube Root	Circle	
					Circum.	Area
3.5	12.25	42.875	1.871	1.518	10.996	9.621
.6	12.96	46.656	1.897	1.533	11.310	10.179
.7	13.69	50.653	1.924	1.547	11.624	10.752
.8	14.44	54.872	1.949	1.560	11.938	11.341
.9	15.21	59.319	1.975	1.574	12.252	11.946
4.	16.	64.	2.	1.587	12.566	12.566
.1	16.81	68.921	2.025	1.601	12.881	13.203
.2	17.64	74.088	2.049	1.613	13.195	13.854
.3	18.49	79.507	2.074	1.626	13.509	14.522
.4	19.36	85.184	2.098	1.639	13.823	15.205
.5	20.25	91.125	2.121	1.651	14.137	15.904
.6	21.16	97.336	2.145	1.663	14.451	16.619
.7	22.09	103.823	2.168	1.675	14.765	17.349
.8	23.04	110.592	2.191	1.687	15.080	18.096
.9	24.01	117.649	2.214	1.698	15.394	18.857
5.	25.	125.	2.236	1.710	15.708	19.635
.1	26.01	132.651	2.258	1.721	16.022	20.428
.2	27.04	140.608	2.280	1.732	16.336	21.237
.3	28.09	148.877	2.302	1.744	16.650	22.062
.4	29.16	157.464	2.324	1.754	16.965	22.902
.5	30.25	166.375	2.345	1.765	17.279	23.758
.6	31.36	175.616	2.366	1.776	17.593	24.630
.7	32.49	185.193	2.387	1.786	17.907	25.518
.8	33.64	195.112	2.408	1.797	18.221	26.421
.9	34.81	205.379	2.429	1.807	18.535	27.340
6.	36.	216.	2.450	1.817	18.850	28.274
.1	37.21	226.981	2.470	1.827	19.164	29.225
.2	38.44	238.328	2.490	1.837	19.478	30.191
.3	39.69	250.047	2.510	1.847	19.792	31.173
.4	40.96	262.144	2.530	1.857	20.106	32.170
.5	42.25	274.625	2.550	1.866	20.420	33.183
.6	43.56	287.496	2.569	1.876	20.734	34.212
.7	44.89	300.763	2.588	1.885	21.049	35.257
.8	46.24	314.432	2.608	1.895	21.363	36.317
.9	47.61	328.509	2.627	1.904	21.677	37.39[illegible]

Squares, Cubes, Square Roots, Cube Roots, Circumferences and Areas

From .1 to 120; by Tenths to 10.

For Circles by Eighths, see pages 130 and 131.

Number or Diam.	Square	Cube	Square Root	Cube Root	Circle	
					Circum.	Area
7.	49.	343.	2.646	1.913	21.991	38.485
.1	50.41	357.911	2.665	1.922	22.305	39.592
.2	51.84	373.248	2.683	1.931	22.619	40.715
.3	53.29	389.017	2.702	1.940	22.934	41.854
.4	54.76	405.224	2.720	1.949	23.248	43.008
.5	56.25	421.875	2.739	1.957	23.562	44.179
.6	57.76	438.976	2.757	1.966	23.876	45.365
.7	59.29	456.533	2.775	1.975	24.190	46.566
.8	60.84	474.552	2.793	1.983	24.504	47.784
.9	62.41	493.039	2.811	1.992	24.819	49.017
8.	64.	512.	2.828	2.	25.133	50.266
.1	65.61	531.441	2.846	2.008	25.447	51.530
.2	67.24	551.368	2.864	2.017	25.761	52.810
.3	68.89	571.787	2.881	2.025	26.075	54.106
.4	70.56	592.704	2.898	2.033	26.389	55.418
.5	72.25	614.125	2.915	2.041	26.704	56.745
.6	73.96	636.056	2.933	2.049	27.018	58.088
.7	75.69	658.503	2.950	2.057	27.332	59.447
.8	77.44	681.472	2.966	2.065	27.646	60.821
.9	79.21	704.969	2.983	2.072	27.960	62.211
9.	81.	729.	3.	2.080	28.274	63.617
.1	82.81	753.571	3.017	2.088	28.588	65.039
.2	84.64	778.688	3.033	2.095	28.903	66.476
.3	86.49	804.357	3.050	2.103	29.217	67.929
.4	88.36	830.584	3.066	2.110	29.531	69.398
.5	90.25	857.375	3.082	2.118	29.845	70.882
.6	92.16	884.736	3.098	2.125	30.159	72.382
.7	94.09	912.673	3.114	2.133	30.473	73.898
.8	96.04	941.192	3.130	2.140	30.788	75.430
.9	98.01	970.299	3.146	2.147	31.102	76.977
10.	100.	1000.	3.162	2.154	31.416	78.540
11.	*121.*	*1331.*	3.317	2.224	34.558	95.033
12.	*144.*	*1728.*	3.464	2.289	37.699	113.10
13.	*169.*	*2197.*	3.606	2.351	40.841	132.73
14.	*196.*	*2744.*	3.742	2.410	43.982	153.94

Squares, Cubes, Square Roots, Cube Roots, Circumferences and Areas

From .1 to 120; by Tenths to 10.

For Circles by Eighths, see pages 130 and 131.

Number or Diam.	Square	Cube	Square Root	Cube Root	Circle	
					Circum.	Area
15	225	3375	3.873	2.466	47.124	176.71
16	256	4096	4.	2.520	50.265	201.06
17	289	4913	4.123	2.571	53.407	226.98
18	324	5832	4.243	2.621	56.549	254.47
19	361	6859	4.359	2.668	59.690	283.53
20	400	8000	4.472	2.714	62.832	314.16
21	441	9261	4.583	2.759	65.973	346.36
22	484	10648	4.690	2.802	69.115	380.13
23	529	12167	4.796	2.844	72.257	415.48
24	576	13824	4.899	2.885	75.398	452.39
25	625	15625	5.	2.924	78.540	490.87
26	676	17576	5.099	2.963	81.681	530.93
27	729	19683	5.196	3.	84.823	572.56
28	784	21952	5.292	3.037	87.965	615.75
29	841	24389	5.385	3.072	91.106	660.52
30	900	27000	5.477	3.107	94.248	706.86
31	961	29791	5.568	3.141	97.389	754.77
32	1024	32768	5.657	3.175	100.53	804.25
33	1089	35937	5.745	3.208	103.67	855.30
34	1156	39304	5.831	3.240	106.81	907.92
35	1225	42875	5.916	3.271	109.96	962.11
36	1296	46656	6.	3.302	113.10	1017.88
37	1369	50653	6.083	3.332	116.24	1075.21
38	1444	54872	6.164	3.362	119.38	1134.11
39	1521	59319	6.245	3.391	122.52	1194.59
40	1600	64000	6.325	3.420	125.66	1256.64
41	1681	68921	6.403	3.448	128.81	1320.25
42	1764	74088	6.481	3.476	131.95	1385.44
43	1849	79507	6.557	3.503	135.09	1452.20
44	1936	85184	6.633	3.530	138.23	1520.53
45	2025	91125	6.708	3.557	141.37	1590.43
46	2116	97336	6.782	3.583	144.51	1661.90
47	2209	103823	6.856	3.609	147.66	1734.94
48	2304	110592	6.928	3.634	150.80	1809.56
49	2401	117649	7.	3.659	153.94	1885.74

Squares, Cubes, Square Roots, Cube Roots, Circumferences and Areas

From .1 to 120; by Tenths to 10.

For Circles by Eighths, see pages 130 and 131.

Number or Diam.	Square	Cube	Square Root	Cube Root	Circle	
					Circum.	Area
50	2500	125000	7.071	3.684	157.08	1963.50
51	2601	132651	7.141	3.708	160.22	2042.82
52	2704	140608	7.211	3.733	163.36	2123.72
53	2809	148877	7.280	3.756	166.50	2206.18
54	2916	157464	7.348	3.780	169.65	2290.22
55	3025	166375	7.416	3.803	172.79	2375.83
56	3136	175616	7.483	3.826	175.93	2463.01
57	3249	185193	7.550	3.849	179.07	2551.76
58	3364	195112	7.616	3.871	182.21	2642.08
59	3481	205379	7.681	3.893	185.35	2733.97
60	3600	216000	7.746	3.915	188.50	2827.43
61	3721	226981	7.810	3.937	191.64	2922.47
62	3844	238328	7.874	3.958	194.78	3019.07
63	3969	250047	7.937	3.979	197.92	3117.25
64	4096	262144	8.	4.	201.06	3216.99
65	4225	274625	8.062	4.021	204.20	3318.31
66	4356	287496	8.124	4.041	207.34	3421.19
67	4489	300763	8.185	4.062	210.49	3525.65
68	4624	314432	8.246	4.082	213.63	3631.68
69	4761	328509	8.307	4.102	216.77	3739.28
70	4900	343000	8.367	4.121	219.91	3848.45
71	5041	357911	8.426	4.141	223.05	3959.19
72	5184	373248	8.485	4.160	226.19	4071.50
73	5329	389017	8.544	4.179	229.34	4185.39
74	5476	405224	8.602	4.198	232.48	4300.84
75	5625	421875	8.660	4.217	235.62	4417.86
76	5776	438976	8.718	4.236	238.76	4536.46
77	5929	456533	8.775	4.254	241.90	4656.63
78	6084	474552	8.832	4.273	245.04	4778.36
79	6241	493039	8.888	4.291	248.19	4901.67
80	6400	512000	8.944	4.309	251.33	5026.55
81	6561	531441	9.	4.327	254.47	5153.00
82	6724	551368	9.055	4.345	257.61	5281.02
83	6889	571787	9.110	4.362	260.75	5410.61
84	7056	592704	9.165	4.380	263.89	5541.77

Squares, Cubes, Square Roots, Cube Roots, Circumferences and Areas

From .1 to 120; by Tenths to 10.

For Circles by Eighths, see pages 130 and 131.

Number or Diam.	Square	Cube	Square Root	Cube Root	Circle	
					Circum.	Area
85	7225	614125	9.220	4.397	267.04	5674.50
86	7396	636056	9.274	4.414	270.18	5808.80
87	7569	658503	9.328	4.431	273.32	5944.68
88	7744	681472	9.381	4.448	276.46	6082.12
89	7921	704969	9.434	4.465	279.60	6221.14
90	8100	729000	9.487	4.481	282.74	6361.73
91	8281	753571	9.539	4.498	285.88	6503.88
92	8464	778688	9.592	4.514	289.03	6647.61
93	8649	804357	9.644	4.531	292.17	6792.91
94	8836	830584	9.695	4.547	295.31	6939.78
95	9025	857375	9.747	4.563	298.45	7088.22
96	9216	884736	9.798	4.579	301.59	7238.23
97	9409	912673	9.849	4.595	304.73	7389.81
98	9604	941192	9.900	4.610	307.88	7542.96
99	9801	970299	9.950	4.626	311.02	7697.69
100	10000	1000000	10.	4.642	314.16	7853.98

FOR NUMBERS LARGER THAN IN TABLES:

SQUARE. To find square of any number 10 times as large as one in table, find square of table number and multiply by the square of 10. Same principle applies for any divisor, as well as for 10. E. g.: Square of 252 = quare of 84 x square of 3 = 7056 x 9 = 63504.

CUBE. To find Cube of any number 10 times as large as one in table find cube of table number and multiply by the cube of 10. Same prin ciple applies for any divisor, as well as for 10. E. g.: Cube of 252 = cube of 84 x cube of 3 = 592704 x 27 = 16,003,008.

CIRCUMFERENCE. To find Circumference of any circle of diameter 10 times as large as one in table, find circumference for table diameter and multiply by 10. Same principle applies for any divisor, as well as for 10. E. g.: Circumference for diameter 252 = circumference for diameter 84 times 3 = 263.89 x 3 = 791.67.

AREA. To find Area of any circle of diameter 10 times as large as one n table, find area for table diameter and multiply by square of 10. Same rinciple applies for any divisor, as well as for 10. E. g.: Area for diameter 2 = area for 84 x square of 3 = 5541.77 x 9 = 49875.93.

Circumferences and Areas of Circles

Diameters Advancing by Eighths to 17⅞

Diameters by Tenths, and up to 100, see pages 124 to 129.

Diam.	Circum.	Area	Diam.	Circum.	Area
...	......	......	4½	14.137	15.904
⅛	0.393	0.012	⅝	14.530	16.800
¼	.785	.050	¾	14.923	17.721
⅜	1.178	.110	⅞	15.315	18.665
½	1.571	.196			
⅝	1.964	.307	5	15.708	19.635
¾	2.356	.442	⅛	16.101	20.629
⅞	2.749	.601	¼	16.493	21.648
			⅜	16.886	22.691
1	3.142	.785	½	17.279	23.758
⅛	3.534	.994	⅝	17.671	24.850
¼	3.927	1.227	¾	18.064	25.967
⅜	4.320	1.485	⅞	18.457	27.109
½	4.712	1.767			
⅝	5.105	2.074	6	18.850	28.274
¾	5.498	2.405	⅛	19.242	29.465
⅞	5.890	2.761	¼	19.635	30.680
			⅜	20.228	31.919
2	6.283	3.142	½	20.420	33.183
⅛	6.676	3.547	⅝	20.813	34.472
¼	7.079	3.976	¾	21.206	35.785
⅜	7.461	4.430	⅞	21.598	37.122
½	7.854	4.909			
⅝	8.247	5.412	7	21.991	38.485
¾	8.639	5.940	⅛	22.384	39.871
⅞	9.032	6.492	¼	22.777	41.282
			⅜	23.169	42.718
3	9.425	7.069	½	23.562	44.179
⅛	9.817	7.670	⅝	23.955	45.664
¼	10.210	8.296	¾	24.347	47.173
⅜	10.603	8.946	⅞	24.740	48.707
½	10.996	9.621			
⅝	11.388	10.321	8	25.133	50.265
¾	11.781	11.045	⅛	25.525	51.849
⅞	12.174	11.793	¼	25.918	53.456
			⅜	26.311	55.088
4	12.566	12.566	½	26.704	56.745
⅛	12.959	13.364	⅝	27.096	58.426
¼	13.352	14.186	¾	27.489	60.132
⅜	13.745	15.033	⅞	27.882	61.862

Circumferences and Areas of Circles

Diameters Advancing by Eighths to 17⅞

Diameters by Tenths, and up to 100, see pages 124 to 129.

Diam.	Circum.	Area	Diam.	Circum.	Area
9	28.274	63.617	13½	42.412	143.14
⅛	28.667	65.397	⅝	42.804	145.80
¼	29.060	67.201	¾	43.197	148.49
⅜	29.452	69.029	⅞	43.590	151.20
½	29.845	70.882			
⅝	30.238	72.760	14	43.982	153.94
¾	30.631	74.662	⅛	44.375	156.70
⅞	31.023	76.589	¼	44.768	159.48
			⅜	45.160	162.30
10	31.416	78.540	½	45.553	165.13
⅛	31.809	80.516	⅝	45.946	167.99
¼	32.201	82.516	¾	46.338	170.87
⅜	32.594	84.541	⅞	46.731	173.78
½	32.987	86.590			
⅝	33.379	88.664	15	47.124	176.71
¾	33.772	90.763	⅛	47.517	179.67
⅞	34.165	92.886	¼	47.909	182.65
			⅜	48.302	185.66
11	34.558	95.033	½	48.695	188.69
⅛	34.950	97.205	⅝	49.087	191.75
¼	35.343	99.402	¾	49.480	194.83
⅜	35.736	101.62	⅞	49.873	197.93
½	36.128	103.87			
⅝	36.521	106.14	16	50.266	201.06
¾	36.914	108.43	⅛	50.658	204.22
⅞	37.306	110.75	¼	51.051	207.39
			⅜	51.444	210.60
12	37.699	113.10	½	51.836	213.82
⅛	38.092	115.47	⅝	52.229	217.08
¼	38.485	117.86	¾	52.622	220.35
⅜	38.877	120.28	⅞	53.014	223.65
½	39.270	122.72			
⅝	39.663	125.19	17	53.407	226.98
¾	40.055	127.68	⅛	53.800	230.33
⅞	40.448	130.19	¼	54.193	233.71
			⅜	54.585	237.10
13	40.841	132.73	½	54.978	240.53
⅛	41.233	135.30	⅝	55.371	243.98
¼	41.626	137.89	¾	55.763	247.45
⅜	42.019	140.50	⅞	56.156	250.95

5% Interest

Dollars	1	2	3	4	5	6	7	8	9	10	20	30	40	50	60	70	80	90	100	200	300
	Number of Days																				
1	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	.01	.01	.01	.01	.01	.01	.01	.03	.08
2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.01	.01	.02	.02	.02	.03	.03	.06	.14
3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.02	.02	.03	.03	.04	.04	.05	.09	.14
4	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.01	.02	.02	.03	.03	.04	.05	.05	.06	.11	.17
5	.00	.00	.00	.00	.00	.00	.01	.01	.01	.01	.01	.02	.03	.04	.04	.05	.06	.06	.07	.14	.21
6	.00	.00	.00	.00	.00	.01	.01	.01	.01	.01	.02	.03	.03	.04	.05	.06	.07	.08	.08	.17	.25
7	.00	.00	.00	.00	.01	.01	.01	.01	.01	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10	.19	.29
8	.00	.00	.00	.00	.01	.01	.01	.01	.01	.01	.02	.03	.05	.06	.07	.08	.09	.10	.11	.22	.33
9	.00	.00	.00	.01	.01	.01	.01	.01	.01	.01	.03	.04	.05	.06	.08	.09	.10	.11	.13	.25	.38
10	.00	.00	.00	.01	.01	.01	.01	.01	.01	.01	.03	.04	.06	.07	.08	.10	.11	.13	.14	.28	.42
20	.00	.01	.01	.01	.01	.02	.02	.02	.03	.03	.06	.08	.11	.14	.17	.20	.22	.25	.28	.56	.83
30	.00	.01	.01	.02	.02	.03	.03	.03	.04	.04	.08	.13	.18	.23	.27	.32	.36	.41	.45	.90	1.35
40	.01	.01	.02	.02	.03	.03	.04	.04	.05	.06	.11	.17	.22	.28	.33	.39	.45	.50	.56	1.11	1.67
50	.01	.01	.02	.03	.03	.04	.05	.06	.06	.07	.14	.21	.28	.35	.42	.49	.56	.63	.69	1.40	2.08
60	.01	.02	.03	.03	.04	.05	.06	.07	.08	.08	.17	.25	.33	.42	.50	.58	.67	.75	.83	1.67	2.50
70	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10	.19	.29	.39	.49	.58	.68	.78	.88	.97	1.94	2.92
80	.01	.02	.03	.04	.05	.07	.08	.09	.10	.11	.22	.33	.45	.56	.67	.78	.89	1.00	1.11	2.20	3.33
90	.01	.03	.04	.05	.06	.08	.09	.10	.11	.13	.25	.38	.50	.63	.75	.88	1.00	1.13	1.25	2.50	3.75
100	.01	.03	.04	.06	.07	.08	.10	.11	.13	.14	.28	.42	.56	.69	.83	.97	1.11	1.25	1.39	2.78	4.17
200	.03	.06	.08	.11	.14	.17	.19	.22	.25	.28	.56	.83	1.11	1.39	1.67	1.95	2.22	2.50	2.78	5.56	8.33
300	.04	.08	.13	.17	.21	.25	.29	.33	.38	.42	.83	1.25	1.80	2.25	2.70	3.15	3.60	4.05	4.50	9.00	13.50
400	.06	.11	.17	.22	.28	.33	.39	.44	.50	.56	1.11	1.67	2.23	2.78	3.34	3.89	4.45	5.00	5.56	11.11	16.67
500	.07	.14	.21	.28	.35	.42	.49	.56	.63	.70	1.39	2.08	2.78	3.47	4.17	4.86	5.56	6.25	6.94	13.99	20.83
600	.08	.17	.25	.33	.42	.50	.58	.67	.75	.83	1.67	2.50	3.34	4.17	5.00	5.83	6.67	7.50	8.33	16.67	25.00
700	.10	.19	.29	.39	.49	.58	.68	.78	.88	.97	1.94	2.92	3.89	4.86	5.84	6.81	7.78	8.75	9.72	19.44	29.17
800	.11	.22	.33	.44	.56	.67	.78	.89	1.00	1.11	2.22	3.33	4.45	5.56	6.67	7.78	8.89	10.00	11.11	22.00	33.33
900	.13	.25	.38	.50	.63	.75	.88	1.00	1.13	1.25	2.50	3.75	5.00	6.25	7.50	8.75	10.00	11.25	12.50	25.00	37.50
1000	.14	.28	.42	.56	.70	.83	.97	1.11	1.25	1.39	2.78	4.17	5.56	6.94	8.33	9.72	11.11	12.50	13.89	27.78	41.67
2000	.28	.56	.83	1.11	1.39	1.67	1.94	2.22	2.50	2.78	5.56	8.33	11.12	13.89	16.67	19.45	22.22	25.00	27.78	55.56	83.33
3000	.42	.83	1.25	1.67	2.08	2.50	2.92	3.33	3.75	4.17	8.33	12.50	18.00	22.50	27.00	31.50	36.00	40.50	45.00	90.00	135.00
4000	.56	1.11	1.67	2.22	2.78	3.33	3.89	4.44	5.00	5.55	11.11	16.67	22.22	27.78	33.33	38.89	44.44	50.00	55.56	111.11	166.67
5000	.69	1.39	2.08	2.78	3.47	4.17	4.86	5.56	6.25	6.94	13.89	20.83	27.78	34.72	41.67	48.61	55.56	62.50	69.44	139.89	208.33

6% Interest

Dollars	Number of Days 1	2	3	4	5	6	7	8	9	10	20	30	40	50	60	70	80	90	100	200	300
1	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$ 0.02	$ 0.02	$ 0.03	$ 0.05
2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.01	.02	.02	.02	.03	.03	.03	.07	.10
3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.02	.02	.03	.03	.04	.04	.05	.05	.10	.15
4	.00	.00	.00	.00	.00	.00	.00	.01	.01	.01	.01	.02	.03	.03	.04	.05	.05	.06	.07	.13	.20
5	.00	.00	.00	.00	.00	.01	.01	.01	.01	.01	.02	.03	.03	.04	.05	.06	.07	.08	.08	.17	.25
6	.00	.00	.00	.00	.01	.01	.01	.01	.01	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10	.20	.30
7	.00	.00	.00	.00	.01	.01	.01	.01	.01	.01	.02	.04	.05	.06	.07	.08	.09	.11	.12	.23	.35
8	.00	.00	.00	.01	.01	.01	.01	.01	.01	.01	.03	.04	.05	.07	.08	.09	.11	.12	.13	.27	.40
9	.00	.00	.00	.01	.01	.01	.01	.01	.01	.02	.03	.05	.06	.08	.09	.11	.12	.14	.15	.30	.45
10	.00	.00	.01	.01	.01	.01	.01	.01	.02	.02	.03	.05	.07	.08	.10	.12	.13	.15	.17	.33	.50
20	.00	.01	.01	.01	.02	.02	.02	.03	.03	.03	.07	.10	.13	.17	.20	.23	.27	.30	.33	.67	1.00
30	.01	.01	.02	.02	.03	.03	.04	.04	.05	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	1.00	1.50
40	.01	.01	.02	.03	.03	.04	.05	.05	.06	.07	.13	.20	.27	.33	.40	.47	.53	.60	.67	1.33	2.00
50	.01	.02	.03	.03	.04	.05	.06	.07	.08	.08	.17	.25	.33	.42	.50	.58	.67	.75	.83	1.67	2.50
60	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00	2.00	3.00
70	.01	.02	.04	.05	.06	.07	.08	.09	.11	.12	.23	.35	.47	.58	.70	.82	.93	1.05	1.17	2.33	3.50
80	.01	.03	.04	.05	.07	.08	.09	.11	.12	.13	.27	.40	.53	.67	.80	.93	1.07	1.20	1.33	2.67	4.00
90	.02	.03	.05	.06	.08	.09	.11	.12	.14	.15	.30	.45	.60	.75	.90	1.05	1.20	1.35	1.50	3.00	4.50
100	.02	.03	.05	.07	.08	.10	.12	.13	.15	.17	.33	.50	.67	.83	1.00	1.17	1.33	1.50	1.67	3.33	5.00
200	.03	.07	.10	.13	.17	.20	.23	.27	.30	.33	.67	1.00	1.33	1.67	2.00	2.33	2.67	3.00	3.33	6.67	10.00
300	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	10.00	15.00
400	.07	.13	.20	.27	.33	.40	.47	.53	.60	.67	1.33	2.00	2.67	3.33	4.00	4.67	5.33	6.00	6.67	13.33	20.00
500	.08	.17	.25	.33	.42	.50	.58	.67	.75	.83	1.67	2.50	3.33	4.17	5.00	5.83	6.67	7.50	8.33	16.67	25.00
600	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	20.00	30.00
700	.12	.23	.35	.47	.58	.70	.82	.93	1.05	1.17	2.33	3.50	4.67	5.83	7.00	8.17	9.33	10.50	11.67	23.33	35.00
800	.13	.27	.40	.53	.67	.80	.93	1.07	1.20	1.33	2.67	4.00	5.33	6.67	8.00	9.33	10.67	12.00	13.33	26.67	40.00
900	.15	.30	.45	.60	.75	.90	1.05	1.20	1.35	1.50	3.00	4.50	6.00	7.50	9.00	10.50	12.00	13.50	15.00	30.00	45.00
1000	.17	.33	.50	.67	.83	1.00	1.17	1.33	1.50	1.67	3.33	5.00	6.67	8.33	10.00	11.67	13.33	15.00	16.67	33.33	50.00
2000	.33	.67	1.00	1.33	1.67	2.00	2.33	2.67	3.00	3.33	6.67	10.00	13.33	16.67	20.00	23.33	26.67	30.00	33.33	66.67	100.00
3000	.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	10.00	15.00	20.00	25.00	30.00	35.00	40.00	45.00	50.00	100.00	150.00
4000	.67	1.33	2.00	2.67	3.33	4.00	4.67	5.33	6.00	6.67	13.33	20.00	26.67	33.33	40.00	46.67	53.33	60.00	66.67	133.33	200.00
5000	.83	1.67	2.50	3.33	4.17	5.00	5.83	6.67	7.50	8.33	16.67	25.00	33.33	41.67	50.00	56.33	66.67	75.00	83.33	166.67	250.00

7% Interest

Dollars	Number of Days: 1	2	3	4	5	6	7	8	9	10	20	30	40	50	60	70	80	90	100	200	300
1	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.01	$0.01	$0.01	$0.01	$0.01	$0.02	$ 0.02	$ 0.02	$ 0.04	$ 0.06
2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.02	.02	.02	.03	.03	.04	.04	.08	.12
3	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.01	.02	.02	.03	.04	.04	.05	.05	.06	.12	.18
4	.00	.00	.00	.00	.00	.00	.01	.01	.01	.01	.02	.02	.03	.04	.05	.05	.06	.07	.08	.16	.23
5	.00	.00	.00	.00	.00	.01	.01	.01	.01	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10	.19	.29
6	.00	.00	.00	.00	.01	.01	.01	.01	.01	.01	.02	.04	.05	.06	.07	.08	.09	.11	.12	.23	.35
7	.00	.00	.00	.01	.01	.01	.01	.01	.01	.01	.03	.04	.05	.07	.08	.10	.11	.12	.14	.27	.41
8	.00	.00	.00	.01	.01	.01	.01	.01	.01	.02	.03	.05	.06	.08	.09	.11	.12	.14	.16	.31	.47
9	.00	.00	.01	.01	.01	.01	.01	.01	.02	.02	.04	.05	.07	.09	.11	.13	.15	.16	.18	.36	.54
10	.00	.00	.01	.01	.01	.01	.01	.02	.02	.02	.04	.06	.08	.10	.12	.14	.16	.18	.19	.38	.58
20	.00	.01	.01	.02	.02	.02	.03	.03	.04	.04	.08	.12	.16	.19	.23	.27	.31	.35	.39	.78	1.17
30	.01	.01	.02	.02	.03	.04	.04	.05	.05	.06	.12	.18	.23	.29	.35	.41	.48	.53	.58	1.17	1.75
40	.01	.02	.02	.03	.04	.05	.05	.06	.07	.08	.16	.23	.31	.39	.47	.54	.62	.70	.78	1.56	2.33
50	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10	.19	.29	.41	.51	.60	.70	.80	.90	.97	1.94	2.92
60	.01	.02	.04	.05	.06	.07	.08	.09	.11	.12	.23	.35	.47	.58	.70	.82	.93	1.05	1.17	2.33	3.50
70	.01	.03	.04	.05	.07	.08	.10	.11	.12	.14	.27	.41	.54	.68	.82	.95	1.09	1.23	1.36	2.72	4.08
80	.02	.03	.05	.06	.08	.09	.11	.12	.14	.16	.31	.47	.63	.79	.93	1.09	1.24	1.40	1.56	3.11	4.67
90	.02	.04	.05	.07	.09	.11	.12	.14	.16	.18	.35	.53	.73	.91	1.09	1.27	1.45	1.63	1.82	3.63	5.44
100	.02	.04	.06	.08	.10	.12	.14	.16	.18	.19	.39	.58	.78	.97	1.17	1.36	1.56	1.75	1.94	3.89	5.83
200	.04	.08	.12	.16	.19	.23	.27	.31	.35	.39	.78	1.17	1.56	1.94	2.33	2.72	3.11	3.50	3.89	7.78	11.67
300	.06	.12	.18	.23	.29	.35	.41	.47	.53	.58	1.17	1.75	2.33	2.92	3.50	4.08	4.67	5.25	5.83	11.67	17.50
400	.08	.16	.23	.31	.39	.47	.54	.62	.70	.78	1.56	2.33	3.11	3.89	4.67	5.44	6.22	7.00	7.78	15.56	23.33
500	.10	.19	.29	.39	.49	.58	.68	.78	.88	.97	1.94	2.92	4.09	5.06	6.03	7.01	7.98	8.95	9.72	19.44	29.17
600	.12	.23	.35	.47	.58	.70	.82	.93	1.05	1.17	2.33	3.50	4.67	5.83	7.00	8.17	9.33	10.50	11.67	23.33	35.00
700	.14	.27	.41	.54	.68	.82	.95	1.09	1.23	1.36	2.72	4.08	5.44	6.80	8.17	9.53	10.89	12.25	13.61	27.22	40.83
800	.16	.31	.47	.62	.78	.93	1.09	1.24	1.40	1.56	3.11	4.67	6.33	7.89	9.33	10.89	12.44	14.00	15.56	31.11	46.67
900	.18	.35	.53	.70	.88	1.05	1.23	1.40	1.58	1.75	3.50	5.25	7.26	9.07	10.89	12.70	14.52	16.33	18.15	36.30	54.44
1000	.19	.39	.58	.78	.97	1.17	1.36	1.56	1.75	1.94	3.89	5.83	7.78	9.72	11.67	13.61	15.56	17.50	19.44	38.89	58.33
2000	.39	.78	1.17	1.56	1.95	2.34	2.73	3.12	3.50	3.89	7.78	11.67	15.56	19.44	23.33	27.22	31.11	35.00	38.89	77.78	116.66
3000	.58	1.17	1.75	2.34	2.92	3.50	4.08	4.67	5.25	5.83	11.67	17.50	23.33	29.17	35.00	40.83	46.67	52.50	58.33	116.67	175.00
4000	.78	1.55	2.33	3.11	3.88	4.56	5.45	6.22	7.00	7.78	15.56	23.33	31.11	38.89	46.67	54.44	62.22	70.00	77.78	155.55	233.33
5000	.97	1.95	2.92	3.90	4.87	5.84	6.81	7.78	8.76	9.73	19.46	29.19	40.89	50.61	60.33	70.05	79.78	89.50	97.22	194.44	291.66

8% Interest

Dollars	Number of Days 1	2	3	4	5	6	7	8	9	10	20	30	40	50	60	70	80	90	100	200	300
1	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.01	$0.01	$0.01	$0.01	$0.02	$0.02	$ 0.02	$ 0.02	$ 0.04	$ 0.07
2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.02	.02	.03	.03	.04	.04	.04	.09	.13
3	.00	.00	.00	.00	.00	.00	.00	.01	.01	.01	.01	.02	.03	.03	.04	.05	.05	.06	.07	.13	.20
4	.00	.00	.00	.00	.00	.01	.01	.01	.01	.01	.02	.03	.04	.04	.05	.06	.07	.08	.09	.18	.27
5	.00	.00	.00	.00	.01	.01	.01	.01	.01	.01	.02	.03	.04	.06	.07	.08	.09	.10	.11	.22	.33
6	.00	.00	.00	.01	.01	.01	.01	.01	.01	.01	.03	.04	.05	.07	.08	.09	.11	.12	.13	.27	.40
7	.00	.00	.00	.01	.01	.01	.01	.01	.01	.02	.03	.05	.06	.08	.09	.11	.12	.14	.16	.31	.47
8	.00	.00	.01	.01	.01	.01	.01	.01	.02	.02	.04	.05	.07	.09	.11	.12	.14	.16	.18	.36	.53
9	.00	.00	.01	.01	.01	.01	.01	.02	.02	.02	.04	.06	.08	.10	.12	.14	.16	.18	.20	.40	.60
10	.00	.00	.01	.01	.01	.01	.02	.02	.02	.02	.04	.07	.09	.11	.13	.16	.18	.20	.22	.44	.67
20	.00	.01	.01	.02	.02	.03	.03	.04	.04	.04	.09	.13	.18	.22	.27	.31	.36	.40	.44	.89	1.33
30	.01	.01	.02	.03	.03	.04	.05	.05	.06	.07	.13	.20	.27	.33	.40	.47	.53	.60	.67	1.33	2.00
40	.01	.02	.03	.04	.04	.05	.06	.07	.08	.09	.18	.27	.36	.44	.53	.62	.71	.80	.89	1.78	2.67
50	.01	.02	.03	.04	.06	.07	.08	.09	.10	.11	.22	.33	.44	.56	.67	.78	.89	1.00	1.11	2.22	3.33
60	.01	.03	.04	.05	.07	.08	.09	.11	.12	.13	.27	.40	.53	.67	.80	.93	1.07	1.20	1.33	2.67	4.00
70	.02	.03	.05	.06	.08	.09	.11	.12	.14	.16	.31	.47	.62	.78	.93	1.09	1.24	1.40	1.56	3.11	4.67
80	.02	.04	.05	.07	.09	.11	.12	.14	.16	.18	.36	.53	.71	.89	1.07	1.24	1.42	1.60	1.78	3.56	5.33
90	.02	.04	.06	.08	.10	.12	.14	.16	.18	.20	.40	.60	.80	1.00	1.20	1.40	1.60	1.80	2.00	4.00	6.00
100	.02	.04	.07	.09	.11	.13	.16	.18	.20	.22	.44	.67	.89	1.11	1.33	1.56	1.78	2.00	2.22	4.44	6.67
200	.04	.09	.13	.18	.22	.27	.31	.36	.40	.44	.89	1.33	1.78	2.22	2.67	3.11	3.56	4.00	4.44	8.89	13.33
300	.07	.13	.20	.27	.33	.40	.47	.53	.60	.67	1.33	2.00	2.67	3.33	4.00	4.67	5.33	6.00	6.67	13.33	20.00
400	.09	.18	.27	.36	.44	.53	.62	.71	.80	.89	1.78	2.67	3.56	4.44	5.33	6.22	7.11	8.00	8.89	17.78	26.67
500	.11	.22	.33	.44	.56	.67	.78	.89	1.00	1.11	2.22	3.33	4.44	5.56	6.67	7.78	8.89	10.00	11.11	22.22	33.33
600	.13	.27	.40	.53	.67	.80	.93	1.07	1.20	1.33	2.67	4.00	5.53	6.67	8.00	9.33	10.67	12.00	13.33	26.67	40.00
700	.16	.31	.47	.62	.78	.93	1.09	1.24	1.40	1.56	3.11	4.67	6.22	7.79	9.33	10.89	12.44	14.00	15.56	31.11	46.67
800	.18	.36	.53	.71	.89	1.07	1.24	1.42	1.60	1.78	3.56	5.33	7.11	8.89	10.67	12.44	14.22	16.00	17.78	35.56	53.33
900	.20	.40	.60	.80	1.00	1.20	1.40	1.60	1.80	2.00	4.00	6.00	8.00	10.00	12.00	14.00	16.00	18.00	20.00	40.00	60.00
1000	.22	.44	.67	.89	1.11	1.33	1.56	1.78	2.00	2.22	4.44	6.67	8.89	11.11	13.33	15.56	17.78	20.00	22.22	44.44	66.67
2000	.44	.89	1.33	1.78	2.22	2.67	3.11	3.56	4.00	4.44	8.89	13.33	17.78	22.22	26.67	31.11	35.56	40.00	44.44	88.89	133.33
3000	.67	1.33	2.00	2.67	3.33	4.00	4.67	5.33	6.00	6.67	13.33	20.00	26.67	33.33	40.00	46.67	53.33	60.00	66.67	133.33	200.00
4000	.89	1.78	2.67	3.56	4.44	5.33	6.22	7.11	8.00	8.89	17.78	26.67	35.56	44.44	53.33	62.22	71.11	80.00	88.89	177.79	266.67
5000	1.11	2.22	3.33	4.44	5.56	6.67	7.78	8.89	10.00	11.11	22.22	33.33	14.44	55.56	66.67	77.78	88.89	100.00	111.11	222.22	333.33

Depreciation

Years	Rate of Depreciation, Percent per Annum											
	1	2	3	4	5	6	7	8	10	12	15	20
	Depreciated Value, Percent of Original Value.											
1	$99.00	$98.00	$97.00	$96.00	$95.00	$94.00	$93.00	$92.00	$90.00	$88.00	$85.00	$80.00
2	98.01	96.04	94.09	92.16	92.25	88.36	86.49	84.64	81.00	77.44	72.25	64.00
3	97.03	94.12	91.27	88.47	85.74	83.06	80.44	77.87	72.90	68.15	61.41	51.20
4	96.06	92.24	88.53	84.93	81.45	78.07	74.81	71.64	65.61	59.97	52.20	40.96
5	95.10	90.39	85.87	81.54	77.38	73.39	69.57	65.91	59.05	52.77	44.37	32.77
6	94.15	88.58	83.30	78.28	73.51	68.99	64.70	60.64	53.14	46.44	37.71	26.21
7	93.21	86.81	80.80	75.15	69.83	64.85	60.17	55.78	47.83	40.87	32.06	20.97
8	92.27	85.08	78.37	72.14	66.34	60.96	55.96	51.32	43.05	35.96	27.25	16.78
9	91.35	83.37	76.02	69.25	63.02	57.30	52.04	47.22	38.74	31.65	23.16	13.42
10	90.44	81.71	73.74	66.48	59.87	53.86	48.40	43.44	34.87	27.85	19.69	10.74
11	89.53	80.07	71.53	63.82	56.88	50.63	45.01	39.96	31.38	24.51	16.74	8.59
12	88.64	78.47	69.38	61.27	54.04	47.59	41.86	36.77	28.24	21.57	14.22	6.87
13	87.75	76.90	67.30	58.82	51.33	44.74	38.93	33.83	25.42	18.98	12.09	5.50
14	86.87	75.36	65.28	56.47	48.77	42.05	36.20	31.12	22.88	16.70	10.28	4.40
15	86.01	73.86	63.33	54.21	46.33	39.53	33.67	28.63	20.59	14.70	8.74	3.52
16	85.15	72.38	61.43	52.04	44.01	37.16	31.31	26.34	18.53	12.93	7.43	2.81
17	84.29	70.93	59.58	49.96	41.82	34.93	29.12	24.23	16.68	11.38	6.31	2.25
18	83.45	69.51	57.80	47.96	39.72	32.83	27.08	22.29	15.01	10.02	5.36	1.80
19	82.62	68.12	56.06	46.04	37.74	30.86	25.19	20.51	13.51	8.81	4.56	1.44
20	81.79	66.76	54.38	44.20	35.85	29.01	23.42	18.87	12.16	7.76	3.88	1.15

Discount Equivalents

To find a net price, multiply list price by the decimal net equivalent of the given discount.

EXAMPLE.—What will be the net price if a discount of 40-10-10-5 is allowed on a list price of $65.00?

SOLUTION.—In the column for Leading Discount 40, and in the horizontal line for Supplementary Discount 10-10-5 at the left, find the decimal net equivalent .4617. Then $65.00×.4617 =$30.01, the net price.

Supplementary Discount	Leading Discount 10	20	30	40	50	60	80
	Decimal Net Equivalent						
2½	.8775	.7800	.6825	.5850	.4875	.3900	.1950
5	.8550	.7600	.6650	.5700	.4750	.3800	.1900
5-2½	.8336	.7410	.6484	.5557	.4631	.3705	.1852
5-5	.8123	.7220	.6318	.5415	.4513	.3610	.1805
10	.8100	.7200	.6300	.5400	.4500	.3600	.1800
10-2½	.7898	.7020	.6143	.5265	.4388	.3510	.1755
10-5	.7695	.6840	.5985	.5130	.4275	.3420	.1710
10-5-2½	.7503	.6669	.5835	.5002	.4168	.3334	.1667
10-10	.7290	.6480	.5670	.4860	.4050	.3240	.1620
10-10-5	.6925	.6156	.5387	.4617	.3848	.3078	.1539
10-10-5-2½	.6730	.6002	.5253	.4502	.3751	.3001	.1500
10-10-10	.6561	.5832	.5103	.4374	.3645	.2916	.1458
10-10-10-10	.5905	.5248	.4593	.3937	.3280	.2624	.1384
10-10-10-10-5	.5609	.4986	.4363	.3740	.3116	.2492	.1234
15	.7550	.6800	.5950	.5100	.4250	.3400	.1700
15-2½	.7459	.6630	.5801	.4972	.4144	.3310	.1655
15-5	.7268	.6460	.5652	.4845	.4038	.3220	.1622
15-10	.6885	.6120	.5355	.4590	.3443	.2758	.1378
20	.7200	.6400	.5600	.4800	.4000	.3195	.1598
20-5	.6840	.6080	.5320	.4560	.3800	.3018	.1508
20-10	.6480	.5760	.5040	.4320	.3600	.2879	.1438
20-10-5	.6156	.5472	.4788	.4104	.3420	.2728	.1364
25	.6750	.6000	.5250	.4500	.3750	.2999	.1495
25-5	.6413	.5700	.4987	.4275	.3562	.2842	.1421
25-10	.6075	.5400	.4725	.4050	.3375	.2692	.1346
25-10-5	.5771	.5130	.4488	.3847	.3206	.2561	.128

Income from Securities

Approximate Returns in Dividends on Stocks, or Running Interest on Bonds, at 4% to 10% on Par Values.

Price Paid, Points	Dividend or Interest Rate on Par Value, 100 Points						
	4	5	6	7	8	9	10
	Percentage Return on Money Invested						
50	8.00	10.00	12.00	14.00	16.00	18.00	20.00
55	7.27	9.09	10.91	12.73	14.55	16.36	18.18
60	6.67	8.33	10.00	11.67	13.33	15.00	16.67
65	6.15	7.69	9.23	10.77	12.31	13.85	15.39
70	5.71	7.14	8.57	10.00	11.43	12.86	14.29
75	5.33	6.67	8.00	9.33	10.67	12.00	13.33
80	5.00	6.25	7.50	8.75	10.00	11.25	12.50
85	4.71	5.88	7.06	8.24	9.41	10.59	11.76
90	4.44	5.56	6.67	7.78	8.89	10.00	11.11
95	4.21	5.26	6.32	7.37	8.42	9.47	10.53
100	4.00	5.00	6.00	7.00	8.00	9.00	10.00
105	3.81	4.76	5.71	6.67	7.67	8.57	9.52
110	3.64	4.55	5.45	6.36	7.27	8.18	9.09
115	3.48	4.35	5.22	6.09	6.96	7.82	8.70
120	3.33	4.17	5.00	5.83	6.67	7.50	8.33
125	3.20	4.00	4.80	5.60	6.40	7.20	8.00
130	3.08	3.85	4.62	5.38	6.15	6.92	7.69
135	2.96	3.71	4.44	5.19	5.93	6.67	7.41
140	2.86	3.57	4.29	5.00	5.71	6.43	7.14
145	2.76	3.45	4.14	4.83	5.52	6.21	6.90
150	2.67	3.33	4.00	4.67	5.33	6.00	6.67
160	2.50	3.13	3.75	4.38	5.00	5.63	6.25
170	2.35	2.94	3.53	4.12	4.71	5.29	5.88
180	2.22	2.78	3.33	3.89	4.44	5.00	5.56
190	2.11	2.63	3.16	3.68	4.21	4.73	5.26
200	2.00	2.50	3.00	3.50	4.00	4.50	5.00
225	1.78	2.22	2.67	3.11	3.56	4.00	4.44
250	*1.60*	2.00	2.40	2.80	3.20	3.60	4.00
275	*1.45*	*1.82*	2.18	2.55	2.91	3.27	3.64
300	*1.33*	*1.67*	2.00	2.33	2.67	3.00	3.33

Yields on Bonds

Average yearly income from bonds bought at various prices and carried to maturity.

5% Bonds

Price Paid, Points	Number of Years to Maturity									
	2	4	6	8	10	14	20	30	40	50
	Average Yearly Percentage Return on Money Invested									
110	....	2.37	3.16	3.55	3.79	4.06	4.25	4.40	4.46	4.50
108	....	2.87	3.51	3.83	4.02	4.24	4.40	4.51	4.56	4.60
106	1.93	3.38	3.87	4.11	4.26	4.42	4.54	4.63	4.67	4.69
104	2.92	3.91	4.24	4.40	4.50	4.61	4.69	4.75	4.78	4.79
102	3.95	4.45	4.62	4.70	4.75	4.80	4.84	4.87	4.89	4.89
100	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
98	6.08	5.56	5.40	5.31	5.26	5.20	5.16	5.13	5.12	5.11
96	7.18	6.14	5.80	5.63	5.53	5.41	5.33	5.27	5.24	5.23
94	8.32	6.74	6.21	5.95	5.80	5.63	5.50	5.41	5.37	5.35
92	9.48	7.35	6.64	6.29	6.08	5.84	5.67	5.55	5.50	5.47
90	....	7.97	7.07	6.63	6.37	6.07	5.86	5.70	5.63	5.60
88	....	8.61	7.52	6.99	6.66	6.30	6.04	5.85	5.77	5.73
86	....	9.27	7.98	7.34	6.97	6.54	6.23	6.01	5.92	5.87
84	....	9.94	8.46	7.72	7.28	6.79	6.43	6.18	6.07	6.01
82	....	....	8.94	8.10	7.60	7.04	6.64	6.34	6.23	6.17
80	....	....	9.44	8.50	7.94	7.31	6.85	6.53	6.39	6.32
78	....	....	9.96	8.90	8.28	7.58	7.07	6.71	6.56	6.49
76	....	....	....	9.32	8.63	7.86	7.30	6.91	6.74	6.66

6% Bonds

Price Paid, Points	Number of Years to Maturity									
	1	2	3	4	5	6	7	8	9	10
	Average Yearly Percentage Return on Money Invested									
105	....	3.39	4.21	4.62	4.86	5.03	5.14	5.23	5.29	5.35
104	1.94	3.90	4.56	4.89	5.08	5.22	5.31	5.38	5.43	5.48
102	3.94	4.94	5.27	5.44	5.54	5.60	5.65	5.69	5.71	5.73
100	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
	8.12	7.09	6.75	6.58	6.48	6.41	6.36	6.32	6.30	6.27
	....	8.21	7.51	7.17	6.97	6.82	6.73	6.66	6.60	6.56
	....	9.36	8.30	7.77	7.46	7.25	7.10	6.99	6.91	6.84
	....	....	9.11	8.40	7.97	7.69	7.49	7.34	7.23	7.13
	....	....	9.94	9.03	8.50	8.14	7.87	7.70	7.55	7.4[illegible]

United States Liberty Loan War Bonds

SERIES	FIRST LOAN			SECOND LOAN		THIRD LOAN	FOURTH LOAN	FIFTH LOAN
Issue Rate of Interest Years to Run..	Original 3½% 15 to 30	Converted 4% 15 to 30	Converted 4¼% 15 to 30	Original 4% 10 to 25	Converted 4¼% 10 to 25	Original 4¼% 10	Original 4¼% 15 to 20	Original
Amount of Issue	$2,000,000,000 Some of which has been converted into 4% and 4¼%	$568,318,450 By conversion of 3½% bonds prior to May 15. 1918.	$376,129,100 By conversion of 3½% bonds or converted 4% bonds.	$3,808,766,150 Some of which has been converted into 4¼% bonds.	$2,884,448,400 By conversion of 4% bonds prior to Nov 9, 1918.	$4,176,516,850	$6,989,047,000	$...........
Date of Issue..	June 15, 1917	Nov. 15, 1917	May 9, 1918 Oct. 24, 1918	Nov. 15, 1917	May 9, 1918	May 9, 1918	Oct. 24, 1918	
Redeemable at Govt. option..	On and after June 15, 1932	On and after June 15, 1932	On and after June 15, 1932	On and after Nov. 15, 1927	On and after Nov. 15, 1927	On and after At Maturity	On and after Oct. 15, 1933	
Maturity.....	June 15, 1947	June 15, 1947	June 15, 1947	Nov. 15, 1942	Nov. 15, 1942	Sept. 15, 1928	Oct. 15, 1938	
Interest Payable	June 15-Dec. 15	June 15-Dec. 15	June 15-Dec. 15	May 15-Nov. 15	May 15-Nov. 15	Mar. 15-Sep. 15	Apr. 15-Oct. 15	
Conversion Privileges	Convertible Into higher rate bonds within six months after issue of such bonds.	Expired Nov. 9, 1918	None	Expired Nov. 9, 1918	None	None	None	
Tax Exemptions.... (Notes below)	Note A	Notes B and C	May 9th issue: B, C, D Oct. 24th issue: B and E	Notes B and C	Notes B, C and D	Notes B, C and D	Notes B and E	

TAX NOTE A. Exempt from all taxes except estate or inheritance taxes.

TAX NOTE B. Exempt from state and local taxes and from normal income tax, but subject to estate, inheritance, super-tax, excess and war profits tax on all incomes and earnings above the normal exemption (incomes from holdings of $5,000 bonds are tax exempt except for estate and inheritance taxes). Undistributed net incomes of corporations invested in U. S. Bonds issued after Sept. 1, 1917, are not subject to the 10% tax imposed by the income tax law on net income remaining undistributed six months after the end of the taxable year.

TAX NOTE C. In addition to above tax exemption, income from not more than $45,000 bonds of this issue or a smaller amount of bonds of this issue not exceeding 1½ times the amount of Fourth Loan Bonds held by the owner is exempt until two years after the war from surtaxes excess and war profits taxes, provided said Fourth Loan Bonds were originally subscribed for and have been continuously owned by the tax-payer up to the date of his tax return.

TAX NOTE D. Bonds owned continuously for at least six months prior to one's death are acceptable at par in payment of any estate or inheritance taxes imposed by the United States under any present or future law.

TAX NOTE E. In addition to above tax exemption interest on not to exceed $30,000 bonds of this issue is exempt until two years after the war from surtaxes, excess and war profits taxes when owned by one individual, partnership, corporation or association.

Yield on Liberty Bonds

Bought at Par and Sold at Higher or Lower Prices, after Holding for One or More Years

Selling at less than par a bond bought at par causes a loss of income rate in any case, and may involve a loss on the principal, as shown by minus signs in the table below.

Only by holding the bond to maturity, or until called for redemption by the government, or by otherwise disposing of it at par and interest can the full rate of income be realized.

Liberty bonds should be held for sale or redemption at par or higher. Prices lower than par are due solely to willingness to sell at a sacrifice, and are not at all due to any lack of value in the bonds themselves.

The table applies only to the 4¼% issues. Proportionate figures for issues of other rates.

Average Yearly Percentage Returns, 4¼% Bonds

Selling Price of a $50.00 Bond	Number of Years Held							
	1	2	3	5	7	10	15	20
	Yearly Percentage Return							
$55.00	14.25	9.25	7.58	6.25	5.68	5.25	4.92	4.75
54.00	12.25	8.25	6.92	5.85	5.39	5.05	4.72	4.65
53.00	10.25	7.25	6.25	5.45	5.11	4.85	4.65	4.55
52.00	8.25	6.25	5.58	5.05	4.82	4.65	4.52	4.45
51.00	6.25	5.25	4.92	4.65	4.54	4.45	4.39	4.35
50.00 (par)	4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.25
49.00	2.25	3.25	3.58	3.85	3.96	4.05	4.12	4.15
48.00	.25	2.25	2.92	3.45	3.68	3.85	3.99	4.05
47.00	- 1.75	1.25	2.25	3.05	3.39	3.65	3.85	3.95
46.00	- 3.75	.25	1.58	2.65	3.11	3.45	3.72	3.85
45.00	- 4.75	- .75	.92	2.25	2.82	3.25	3.59	3.75
44.00	- 6.75	- 1.75	.25	1.85	2.54	3.05	3.45	3.65
43.00	- 8.75	- 2.75	- .42	1.45	2.25	2.85	3.32	3.55
42.00	-10.75	- 3.75	- 1.08	1.05	1.96	2.65	3.19	3.45
41.00	*-12.75*	- 4.75	- 1.75	.65	1.68	2.45	3.05	3.35
40.00	*-14.75*	- 5.75	- 2.42	.25	1.39	2.25	2.92	3.25

Postal Rates and Classifications

Domestic Mail Matter

Domestic mail includes matter deposited in the mails for local delivery or transmission from one place to another within the United States, or to or from the possessions of the United States.

Domestic rates apply generally to mail sent from the United States to Canada, Cuba, Mexico, the Republic of Panama and the United States postal agency at Shanghai, China, and matter addressed to officers or members of the crew of vessels of war of the United States.

POSTAL CARDS—2 cents each to all parts of the United States, and Canada. (Pre-War rate, 1 cent.)

LOCAL, OR "DROP" LETTERS—2 cents for each ounce or fraction thereof.

FIRST CLASS—Letters and all other written matter, whether sealed or unsealed, and all other matter, sealed or fastened in any manner so that it cannot be easily examined—3 cents for each ounce or fraction thereof. (Pre-War rate, 2 cents for each ounce or fraction thereof.)

FORM LETTERS, if mailed in quantities of twenty or more at one time at a post office, can be filled in, signed and mailed, unsealed, under third-class postage rates.

SECOND CLASS—Only for publishers and news agents—special zone rate. Newspapers and periodicals (regular second-class publications) can be mailed by the public at the rate of 1 cent for each 4 ounces or fraction thereof.

THIRD CLASS—Printed matter, in unsealed wrappers only (all matter enclosed in notches envelopes must pay letter rates)—1 cent for each 2 ounces or fraction thereof, which must be fully prepaid. This includes circulars, chromos, engravings, handbills, lithographs, music, pamphlets, proof-sheets and manuscript accompanying the same, reproductions by the electric pen, hectograph, metallograph, papyrograph, and in short any reproductions upon paper, by any process except handwriting, the copying press typewriter and the neostyle process. Limit of weight, 4 pounds.

FOURTH CLASS—See Parcel Post rates, following pages.

Foreign Mail Matter

Canada, Cuba, Mexico and Panama—generally same classification and rates as in the United States.

Postal Union Rates

LETTERS—5 cents for 1 ounce or fraction; 3 cents for each additional ounce or fraction.

PRINTED MATTER, periodicals, circulars, books, etc.—1 cent for each 2 ounces or fraction thereof.

COMMERCIAL PAPERS, etc.—5 cents for first 10 ounces or fraction *thereof; 1 cent for each* additional 2 ounces or fraction thereof.

MERCHANDISE SAMPLES—2 cents for first 4 ounces or fraction *thereof; 1 cent for each* additional 2 ounces or fraction thereof.

POSTAL CARDS—2 cents for a single card; 4 cents for double return card.

Domestic Parcel Post Rates

In-Effect March 15, 1918

See Maps on following pages

Weight Pounds	First Zone: Local Rate	First Zone: Zone Rate 50 miles	2nd Zone 50 to 150 miles Rate	3rd Zone 150 to 300 miles Rate	4th Zone 300 to 600 miles Rate	5th Zone 600 to 1,000 miles Rate	6th Zone 1,000 to 1,400 miles Rate	7th Zone 1,400 to 1,800 miles Rate	8th Zone all over 1,800 miles Rate
1	$0.05	$0.05	$0.05	$0.06	$0.07	$0.08	$0.09	$0.11	$0.12
2	.06	.06	.06	.08	.11	.14	.17	.21	.24
3	.06	.07	.07	.10	.15	.20	.25	.31	.36
4	.07	.08	.08	.12	.19	.26	.33	.41	.48
5	.07	.09	.09	.14	.23	.32	.41	.51	.60
6	.08	.10	.10	.16	.27	.38	.49	.61	.72
7	.08	.11	.11	.18	.31	.44	.57	.71	.84
8	.09	.12	.12	.20	.35	.50	.65	.81	.96
9	.09	.13	.13	.22	.39	.56	.73	.91	1.08
10	.10	.14	.14	.24	.43	.62	.81	1.01	1.20
11	.10	.15	.15	.26	.47	.68	.89	1.11	1.32
12	.11	.16	.16	.28	.51	.74	.97	1.21	1.44
13	.11	.17	.17	.30	.55	.80	1.05	1.31	1.56
14	.12	.18	.18	.32	.59	.86	1.13	1.41	1.68
15	.12	.19	.19	.34	.63	.92	1.21	1.51	1.80
16	.13	.20	.20	.36	.67	.98	1.29	1.61	1.92
17	.13	.21	.21	.38	.71	1.04	1.37	1.71	2.04
18	.14	.22	.22	.40	.75	1.10	1.45	1.81	2.16
19	.14	.23	.23	.42	.79	1.16	1.53	1.91	2.28
20	.15	.24	.24	.44	.83	1.22	1.61	2.01	2.40
21	.15	.25	.25	.46	.87	1.28	1.69	2.11	2.52
22	.16	.26	.26	.48	.91	1.34	1.77	2.21	2.64
23	.16	.27	.27	.50	.95	1.40	1.85	2.31	2.76
24	.17	.28	.28	.52	.99	1.46	1.93	2.41	2.88
25	.17	.29	.29	.54	1.03	1.52	2.01	2.51	3.00
26	.18	.30	.30	.56	1.07	1.58	2.09	2.61	3.12
27	.18	.31	.31	.58	1.11	1.64	2.17	2.71	3.24
28	.19	.32	.32	.60	1.15	1.70	2.25	2.81	3.36
29	.19	.33	.33	.62	1.19	1.76	2.33	2.91	3.48
30	.20	.34	.34	.64	1.23	1.82	2.41	3.01	3.60
31	.20	.35	.35	.66	1.27	1.88	2.49	3.11	3.72
32	.21	.36	.36	.68	1.31	1.94	2.57	3.21	3.84
33	.21	.37	.37	.70	1.35	2.00	2.65	3.31	3.96
34	.22	.38	.38	.72	1.39	2.06	2.73	3.41	4.08
35	.22	.39	.39	.74	1.43	2.12	2.81	3.51	4.20
36	.23	.40	.40	.76	1.47	2.18	2.89	3.61	4.32
37	.23	.41	.41	.78	1.51	2.24	2.97	3.71	4.44
38	.24	.42	.42	.80	1.55	2.30	3.05	3.81	4.56
39	.24	.43	.43	.82	1.59	2.36	3.13	3.91	4.68
40	.25	.44	.44	.84	1.63	2.42	3.21	4.01	4.80
41	.25	.45	.45	.86	1.67	2.48	3.29	4 11	4.92
42	.26	.46	.46	.88	1.71	2.54	3.37	4.21	5.04
43	.26	.47	.47	.90	1.75	2.60	3.45	4.31	5.16
44	.27	.48	.48	.92	1.79	2.66	3.53	4.41	5.28
45	.27	.49	.49	.94	1.83	2.72	3.61	4.51	5.40
46	.28	.50	.50	.96	1.87	2.78	3.69	4.61	5.52
47	.28	.51	.51	.98	1.91	2.84	3.77	4.71	5.64
48	.29	.52	.52	1.00	1.95	2.90	3.85	4.81	5.76
49	.29	.53	.53	1.02	1.99	2.96	3.93	4.91	5.8[illegible]
50	.30	.54	.54	1.04	2.03	3.02	4.01	5.01	6.[illegible]

Domestic Parcel Post Rates—Continued

See Maps on following pages

Weight Pounds	First Zone Local Rate	First Zone Zone Rate 50 miles	2nd Zone 50 to 150 miles Rate	3rd Zone 150 to 300 miles Rate
51	$0.30	$0.55	$0.55	$1.06
52	.31	.56	.56	1.08
53	.31	.57	.57	1.10
54	.32	.58	.58	1.12
55	.32	.59	.59	1.14
56	.33	.60	.60	1.16
57	.33	.61	.61	1.18
58	.34	.62	.62	1.20
59	.34	.63	.63	1.22
60	.35	.64	.64	1.24
61	.35	.65	.65	1.26
62	.36	.66	.66	1.28
63	.36	.67	.67	1.30
64	.37	.68	.68	1.32
65	.37	.69	.69	1.34
66	.38	.70	.70	1.36
67	.38	.71	.71	1.38
68	.39	.72	.72	1.40
69	.39	.73	.73	1.42
70	.40	.74	.74	1.44

Parcels May Be Insured Against Damage or Loss

and

May Also Be Sent C. O. D.

To Money Order Post Offices only

Insurance Rates

Value, not over $5.00.....fee 3c
Value, not over $25.00.....fee 5c
Value, not over $50.00.....fee 10c
Value, not over $100.00.....fee 25c

C. O. D. Rates

(Which include insurance)
Amount due Sender

Not over $50.00..........fee 10c
Not over $100.00..........fee 25c

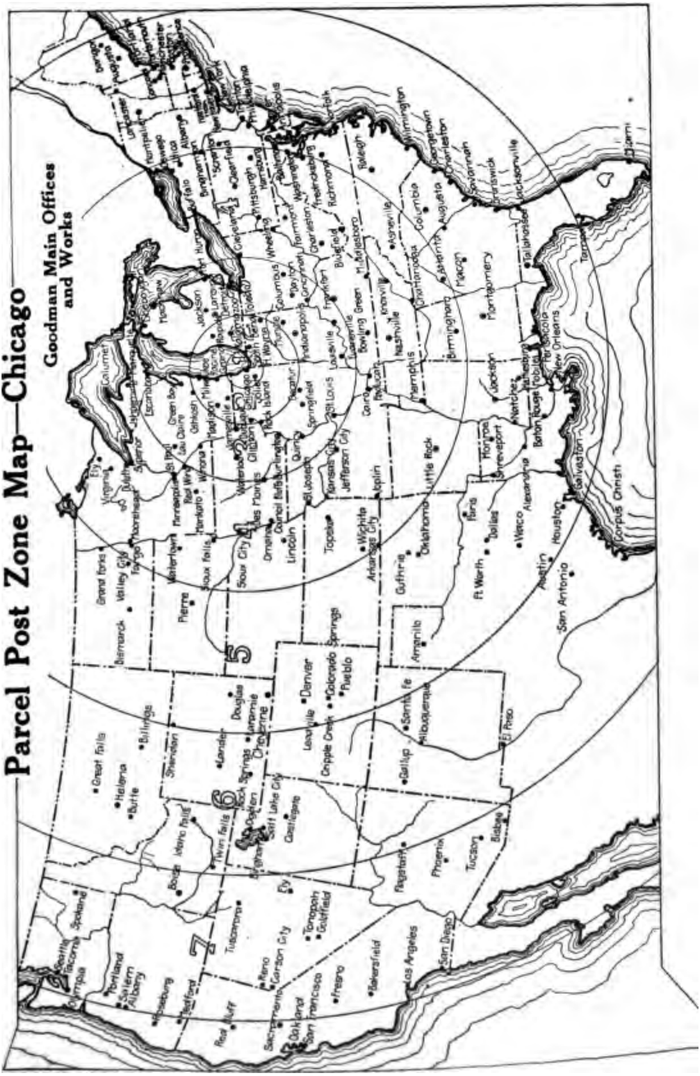
Parcels weighing 4 ounces or less, except books, seeds, plants, etc., 1 cent for each ounce or fraction thereof, any distance.

Parcels weighing 8 ounces or less, containing books, seeds, cuttings, bulbs, roots, scions and plants, 1 cent for each 2 ounces or fraction thereof, regardless of distance.

Parcels weighing more than 8 ounces, containing books, seeds, plants, etc., parcels of miscellaneous printed matter weighing more than 4 pounds and all other parcels of fourth-class matter weighing more than 4 ounces are chargeable, according to distance or zone, at the pound rates shown in the above table, a fraction of a pound being considered a full pound.

THE LIMIT OF WEIGHT of fourth-class matter is 70 pounds for parcels mailed for delivery within the first, second and third zones, and 50 pounds for all other zones.

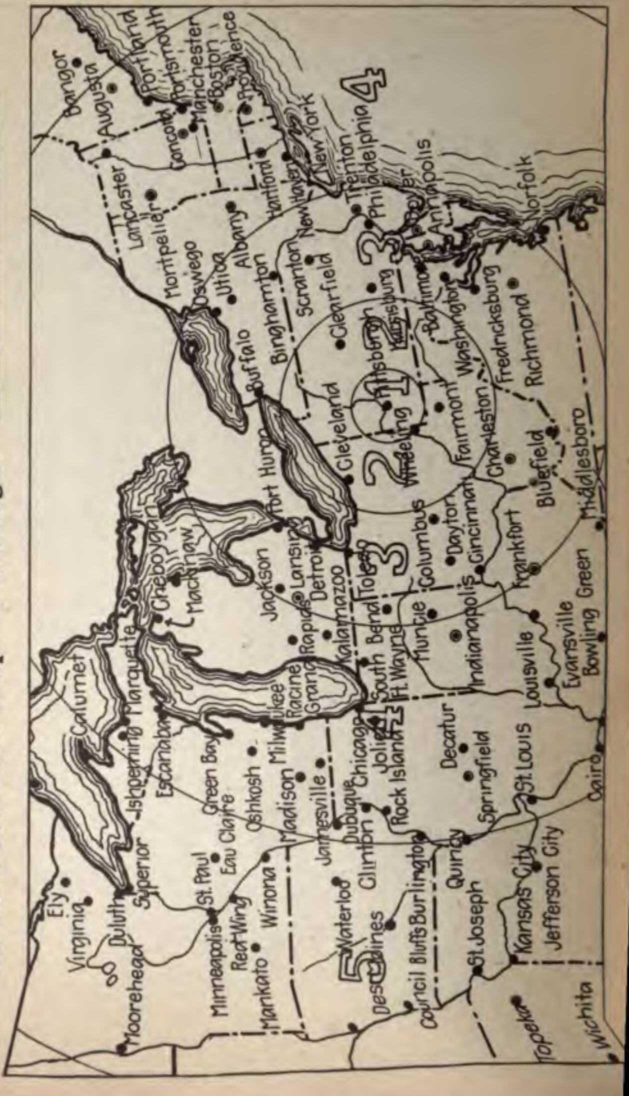
LIMIT OF SIZE. Parcel post matter may not exceed 84 inches in length and girth combined. In measuring a parcel the greatest distance in a straight line between the ends (but *not around the parcel*), is taken as its length, while the distance *around the parcel* at its thickest part is taken as its girth. *For example, a parcel 35 inches long, 10 inches wide and 5 inches high measures 65 inches in length and girth combined.*



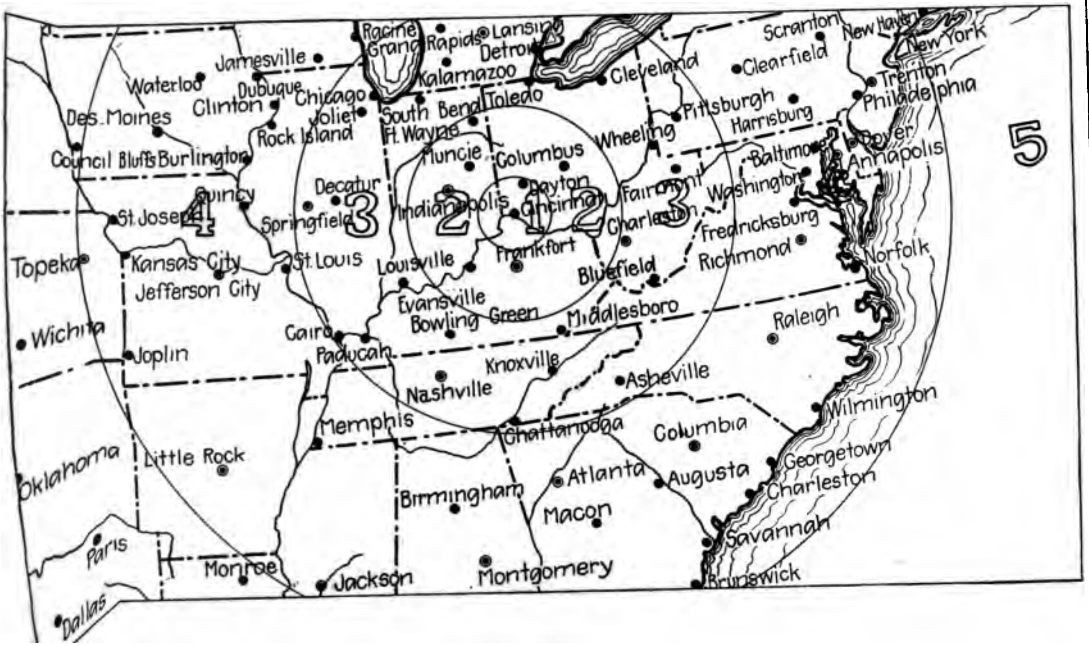
Parcel Post Zone Map—Chicago

Goodman Main Offices and Works

Parcel Post Zone Map—Pittsburgh. Goodman Repair and Supply House.



Parcel Post Zone Map—Cincinnati.



Population of the United States

Estimated 1918

Total—States, Territories and Possessions, 113,235,727

States, Territories and District of Columbia

Total, 102,821,000

Alabama	2,332,608	Montana	459,494
Alaska	65,973	Nebraska	1,271,375
Arizona	255,544	Nevada	106,734
Arkansas	1,739,723	New Hampshire	442,506
California	2,938,654	New Jersey	2,948,017
Colorado	962,060	New Mexico	410,283
Connecticut	1,244,479	New York	10,273,375
Delaware	213,380	North Carolina	2,403,738
Dist. Columbia	363,980	North Dakota	739,201
Florida	893,493	Ohio	5,150,356
Georgia	2,856,065	Oklahoma	2,202,081
Idaho	428,586	Oregon	835,741
Illinois	6,152,257	Pennsylvania	8,522,017
Indiana	2,816,817	Rhode Island	613,315
Iowa	2,358,066	South Carolina	1,625,475
Kansas	1,829,545	South Dakota	698,509
Kentucky	2,379,639	Tennessee	2,288,004
Louisiana	1,829,130	Texas	4,429,566
Maine	772,489	Utah	434,083
Maryland	1,362,807	Vermont	363,669
Massachusetts	3,719,156	Virginia	2,192,019
Michigan	3,054,854	Washington	1,534,221
Minnesota	2,279,603	West Virginia	1,386,038
Mississippi	1,951,674	Wisconsin	2,500,350
Missouri	3,410,692	Wyoming	179,559

Possessions

Total, 10,414,727

Hawaii	232,858	Canal Zone, Guam, Samoa	77,891
Philippine Islds. (1917)	8,879,999		
Porto Rico	1,223,981		

Important Cities

In Order of Population

1.	New York, N. Y	5,896,044
2.	Chicago, Ill	2,547,201
3.	Philadelphia, Pa	1,735,514
4.	Detroit, Mich	850,000
5.	St. Louis, Mo	786,630
6.	Boston, Mass	772,997
7.	Cleveland, Ohio	690,837
8.	Baltimore, Md	625,000
9.	Pittsburgh, Pa	586,196
10.	Los Angeles, Cal	533,535
	Buffalo, N. Y	475,781
	San Francisco, Cal	471,023
	Milwaukee, Wis	445,008
	Newark, N. J	418,789
	Cincinnati, Ohio	414,248
	New Orleans, La	377,010
	Minneapolis, Minn	373,448
	Washington, D. C	369,282
	Seattle, Wash	366,445
	Jersey City, N. J	312,557
	Portland, Ore	308,399
	Kansas City, Mo	305,816
	Indianapolis, Ind	277,479
	Denver, Colo	268,439
	Rochester, N. Y	264,714
	Providence, R. I	259,895
	St. Paul, Minn	252,465
	Louisville, Ky	240,808
	Columbus, Ohio	220,035
	Oakland, Cal	206,405
	Toledo, Ohio	202,010
	Atlanta, Ga	196,144
	Birmingham, Ala	189,716
	Worcester, Mass	170,280
	Omaha, Neb	167,741
	Richmond, Va	158,702
	Syracuse, N. Y	158,514
	New Haven, Conn	158,000
	Spokane, Wash	157,656
	Memphis, Tenn	151,877
	Scranton, Pa	149,541
	Paterson, N. J	140,512
	Bridgeport, Conn	140,000
	Grand Rapids, Mich	132,861
	Fall River, Mass	129,8[illegible]

Population of the United States

Important Cities—Continued

Dallas, Texas	129,632	Charleston, S. C	61,041
Dayton, Ohio	128,939	Pawtucket, R. I	60,666
San Antonio, Texas	128,215	Berkeley, Cal	60,427
Hartford, Conn	122,000	New Britain, Conn	60,000
New Bedford, Mass	121,622	Altoona, Pa	59,712
Salt Lake City, Utah	121,233	Atlantic City, N. J	59,515
Nashville, Tenn	118,136	Mobile, Ala	59,201
Tacoma, Wash	117,446	Knoxville, Tenn	59,112
Houston, Tex	116,878	Little Rock, Ark	58,716
Wilmington, Del	115,000	Sioux City, Iowa	58,568
Lowell, Mass	114,366	Covington, Ky	57,768
Cambridge, Mass	114,293	Flint, Mich	57,386
Trenton, N. J	113,974	Rockford, Ill	56,739
Youngstown, Ohio	112,282	Saginaw, Mich	56,469
Reading, Pa	111,607	San Diego, Cal	56,412
Albany, N. Y	111,077	Pueblo, Colo	56,084
Fort Worth, Tex	109,597	Binghamton, N. Y	55,791
Springfield, Mass	109,298	York, Pa	52,770
Camden, N. J	108,117	Springfield, Ohio	52,296
Lynn, Mass	104,534	Malden, Mass	52,243
Des Moines, Iowa	104,052	Haverhill, Mass	51,870
Schenectady, N. Y	103,774	Lancaster, Pa	51,437
Yonkers, N. Y	103,066	Augusta, Ga	50,642
Lawrence, Mass	102,923	Kalamazoo, Mich	50,408
Kansas City Kan	102,020	Davenport, Iowa	49,618
Oklahoma City, Okla	97,588	Topeka, Kan	49,538
Duluth, Minn	97,077	Salem, Mass	49,538
Waterbury, Conn	97,000	Chelsea, Mass	48,405
Akron, Ohio	93,604	Bay City, Mich	48,390
Somerville, Mass	91,218	McKeesport, Pa	48,299
Norfolk, Va	91,148	Racine, Wis	47,465
Utica, N. Y	89,272	Superior, Wis	47,167
Elizabeth, N. J	88,830	Lincoln, Neb	46,902
St. Joseph, Mo	86,498	Roanoke, Va	46,282
Manchester, N. H	79,607	Macon, Ga	46,099
Jacksonville, Fla	79,065	Woonsocket, R. I	45,365
Wilkes-Barre, Pa	78,334	Newton, Mass	44,614
Hoboken, N. J	78,324	West Hoboken, N. J	44,386
Troy, N. Y	78,094	Quincy, Mass	44,318
Fort Wayne, Ind	78,014	Butte, Mont	44,057
East St. Louis, Ill	77,312	Montgomery, Ala	44,039
Evansville, Ind	76,981	East Orange, N. J	43,761
Erie, Pa	76,592	Wheeling, W. Va	43,657
Passaic, N. J	74,478	Pittsfield, Mass	43,004
Wichita, Kan	73,597	Galveston, Tex	42,650
Harrisburg, Pa	73,276	Fitchburg, Mass	42,419
Bayonne, N. J	72,204	Lexington, Ky	41,997
Peoria, Ill	72,184	Newcastle, Pa	41,915
South Bend, Ind	70,967	Chester, Pa	41,857
Johnstown, Pa	70,473	Hamilton, Ohio	41,338
Savannah, Ga	69,250	Elmira, N. Y	41,278
Brockton, Mass	69,152	Springfield, Mo	41,169
El Paso, Tex	69,149	Charlotte, N. C	40,759
Sacramento, Cal	68,984	Portsmouth, Va	40,693
Terre Haute, Ind	67,361	Everett, Mass	40,160
Holyoke, Mass	66,503	Dubuque, Iowa	40,096
Allentown, Pa	65,109	Joliet, Ill	38,549
Portland, Me	64,720	Cedar Rapids, Iowa	38,033
Springfield, Ill	62,623	Auburn, N. Y	37,823
Canton, Ohio	62,566	Taunton, Mass	37,023
Tampa, Fla	62,389	Quincy, Ill	36,837
Chattanooga, Tenn	61,575	Oshkosh, Wis	36,54[illegible]

The World War

Chronology of Principal Events

1914

June 28—Archduke Ferdinand and wife assassinated in Sarajevo, Bosnia.

July 28—Austria-Hungary declares war on Serbia.

Aug. 1—Germany declares war on Russia.

Aug. 4—France declares war on Germany; Germany declares war on Belgium; Great Britain sends Belgium neutrality ultimatum to Germany; British army mobilized and state of war between Great Britain and Germany is declared. President Wilson issues neutrality proclamation.

Aug. 5—Germans begins fighting on Belgian frontier.

Aug. 6—Austria declares war on Russia.

Aug. 10—France declares war on Austria-Hungary.

Aug. 12—Great Britain declares war on Austria-Hungary; Montenegro declares war on Germany.

Aug. 23—Japan declares war on Germany.

Aug. 25—Japan and Austria break off diplomatic relations.

Sept. 2—Government of France transferred to Bordeaux.

Sept. 4—Germans cross the Marne.

Sept. 5—England, France, and Russia sign pact to make no separate peace.

Sept. 6—French win battle of Marne.

Sept. 14—Battle of Aisne starts; German retreat halted.

Oct. 29—Turkey begins war on Russia.

Nov. 7—Tsingtao falls before Japanese troops.

1915

Jan. 24—British win naval battle in North sea.

Feb. 12—Germans drive Russians from positions in East Prussia, taking 26,000 prisoners.

Feb. 18—German blockade of English and French coasts put into effect.

Feb. 21—American steamer Evelyn sunk by mine in North sea.

Feb. 22—American steamer Carib sunk by mine in North sea.

Feb. 28—Dardanelles entrance forts capitulate to English and French.

March 22—Fort of Przemysl surrenders to Russians.

March 23—Allies land troops on Gallipoli peninsula.

May 7—Liner Lusitania torpedoed and sunk by German submarine off the coast of Ireland with the loss of more than 1,000 lives, 102 Americans.

May 23—Italy declares war on Austria.

June 3—Germans recapture Przemysl with Austrian help.

Aug. 31—Italy declares war on Turkey.

Sept. 1—Ambassador Bernstorff announces Germans will sink no more liners without warning.

Sept. 4—German submarine torpedoes liner Hesperian.

Oct. 5—Russia and Bulgaria sever diplomatic relations; Russian, French, British, Italian and Serbian diplomatic representatives ask for passports in Sofia.

Oct. 10—Gen. Mackensen's forces take Belgrade.

Oct. 12—Edith Cavell executed by Germans.

Oct. 13—Bulgaria declares war on Serbia.

Oct. 15—Great Britain declares war on Bulgaria.

Oct 16—France declares war on Bulgaria.

Oct. 19—Russia and Italy declare war on Bulgaria.

Dec. 4—Ford "peace party" sails for Europe.

Dec. 8-9—Allies defeated in Macedonia.

Dec. 15—Sir John Douglas Haig succeeds Sir John French as chief of English armies on west front.

1916

Jan. 9—British evacuate Gallipoli peninsula.

Feb. 22—Crown prince's army begins attack on Verdun.

March 8—Germany declares war on Portugal.

March 15—Austria-Hungary declares war on Portugal.

March 24—Steamer Sussex torpedoed and sunk.

The World War—Continued

April 29—British troops at Kut-el-Amara surrender to Turks.

May 4—Germany makes promises to change methods of submarine warfare.

May 13—Austrians begin great offensive against Italians in Trentino.

May 31—Great naval battle off Danish coast.

June 5—Lord Kitchener lost with cruiser Hampshire.

July 9—German merchant submarine Deutschland arrives at Baltimore.

Aug. 27—Italy declares war on Germany; Roumania enters war on side of allies.

Aug. 29—Field Marshal von Hindenburg made chief of staff of German armies, succeeding Gen. von Falkenhayn.

Nov. 6—Submarine sinks British passenger steamer Arabia.

Nov. 7—Submarine sinks American steamer Columbian.

Nov. 8—Russian army invades Transylvania, Hungary.

Nov. 9—Austro-German armies defeat Russians in Volhynia, and take 4,000 prisoners.

Nov. 21—British hospital ship Britannic sunk by mine in Ægean sea.

Nov. 28—Roumanian government abandons Bucharest and moves capital to Jassy.

Dec.8—Gen von Mackensen captures big Roumanian army in Prohova valley.

Dec. 19—Lloyd George declines German peace proposals.

Dec. 26—Germany proposes to President Wilson "an immediate meeting of delegates of the belligerents."

1917

Jan. 31—Germany announces unrestricted submarine warfare.

Feb. 3—President Wilson reviews submarine controversy before congress; United States severs diplomatic relations with Germany; American steamer Housatonic sunk without warning.

Feb. 12—United States refuses German request to discuss matters of difference unless Germany withdraws *unrestricted* submarine warfare order.

Feb. 14—Von Bernstorff sails for Germany.

Feb. 25—British under Gen. Maude capture Kut-el-Amara; submarine sinks liner Laconia without warning; many lost, including two Americans.

Feb. 26—President Wilson asks congress for authority to arm American merchantships.

Feb. 28—Secretary Lansing makes public Zimmerman note to Mexico, proposing Mexican-Japanese-German alliance.

March 15—Czar Nicholas of Russia abdicates.

March 21—American oil steamer Healdton torpedoed without warning.

March 22—United States recognizes new government of Russia.

April 2—President Wilson asks congress to declare that acts of Germany constitute a state of war; submarine sinks American steamer Aztec without warning.

April 4—United States senate passes resolution declaring a state of war exists with Germany.

April 6—House passes war resolution, and President Wilson signs joint resolution of congress.

April 8—Austria declares severance of diplomatic relations with United States.

April 20—Turkey severs diplomatic relations with the United States.

April 28—Congress passes selective service act for raising of army of 500,000; Guatemala severs diplomatic relations with Germany.

May 14—Espionage act becomes law by passing senate.

May 18—President Wilson signs selective service act.

June 5—Nearly 10,000,000 men in U. S. register for military service.

June 12—King Constantine of Greece abdicates.

June 13—Gen. Pershing and staff arrive in Paris.

June 15—First Liberty loan closes with large oversubscription.

June 26—First contingent American troops under Gen. Sibert arrives in France.

June 29—Greece severs diplomatic relations with Teutonic allies.

July 9—President Wilson places food and fuel under federal control.

July 14—Aircraft appropriation bill of $640,000,000 passes house Chancelor von Bethmann-Hollweg

The World War—Continued

resignation forced by German political crisis.

July 18—United States government orders censorship of telegrams and cablegrams crossing frontiers.

July 22—Siam declares war on Germany.

July 28—United States war industries board created to supervise expenditures.

Sept. 16—Russia proclaims new republic by order of Premier Kerensky.

Oct. 27—Formal announcement made that American troops in France had fired their first shots in the war.

Oct. 29—Italian Isonzo front collapses and Austro-German army reaches outposts of Udine.

Nov. 1—Secretary Lansing makes public the Luxburg "spurlos versenkt" note.

Nov. 9—Permanent interallied military commission created.

Nov. 24—Navy department announces capture of first German submarine by American destroyer.

Nov. 28—Bolsheviki get absolute control of Russian assembly in Russian elections.

Dec. 6—Submarine sinks the Jacob Jones, first regular warship of American navy destroyed.

Dec. 7—Congress declares war on Austria-Hungary.

Dec. 8—Jerusalem surrenders to Gen. Allenby's forces.

Dec. 26—President Wilson issues proclamation taking over railroads.

1918

Jan. 28—Russia and Roumania sever diplomatic relations.

Feb. 2—United States troops take over their first sector, near Toul.

Feb. 6—United States troopship Tuscania sunk by submarine, 126 lost.

March 1—Americans repulse German attack on Toul sector.

March 2—Treaty of peace with Germany signed by Bolsheviki at Brest-Litovsk.

March 4—Germany and Roumania sign armistice on German terms.

March 23—"Mystery gun" shells Paris.

April 26—British and French *navies "bottle up"* Zeebrugge.

May 10—British navy bottles up *Ostend.*

May 24—British ship Moldavia, carrying American troops, torpedoed; 56 lost.

June 3—Five German submarines attack U. S. coast and sink eleven ships.

June 5—U. S. marines fight on the Marne near Chateau Thierry.

June 22—Italians defeat Austrians on the Piave.

July 18—Gen. Foch launches allied offensive, with French, American, British, Italian and Belgian troops.

July 21—Americans and French capture Chateau Thierry.

July 30—German crown prince flees from the Marne and withdraws army.

Aug. 4—Americans take Fismes.

Aug. 5—American troops landed at Archangel.

Aug. 7—Americans cross the Vesle.

Sept. 29—Allies cross Hindenburg line.

Sept. 30—Bulgaria surrenders, after successful allied campaign in Balkans.

Oct. 5—Germans start abandonment of Lille and burn Douai.

Oct. 11—American transport Otranto torpedoed and sunk: 500 lost.

Oct. 13—Foch's troops take Laon and La Fere.

Oct. 17—Allies capture Lille, Bruges, Zeebrugge, Ostend, and Douai.

Oct. 27—German government asks President Wilson to state terms.

Oct. 29—Austria opens direct negotiations with Secretary Lansing.

Oct. 31—Turkey surrenders; Austrians utterly routed by Italians; lose 50,000; Austrian envoys, under white flag, enter Italian lines.

Nov. 1—Allied conference at Versailles fixes peace terms for Germany.

Nov. 3—Austria signs armistice amounting virtually to unconditional surrender.

Nov. 4—Allied terms are sent to Germany.

Nov. 7—Germany's envoys enter allied lines by arrangement.

Nov. 9—Kaiser Wilhelm abdicates and crown prince renounces throne.

Nov. 11—Armistice signed and hostilities cease.

GOODMAN
MINE EQUIPMENT

FOR

CUTTING
LOADING
GATHERING
HAULING

Goodman Electric Breast Machine

Standard Type

Fitted with Chain Guards

The Mining Machine with Compound Wound Motor, enabling it to adapt itself to variations in the cutting and voltage.

Its motor is placed lengthwise, giving ample room for good bearings and wide-face pinion.

All gears are large, assuring ample strength and durability.

Has only one worm gear, and that a large one.

All parts are designed with generous proportions, for needed strength and durability.

Has under-running chain, which permits cutting close to the bottom.

Fitted with chain guard, when so required, for protection of men and meeting all legal requirements.

Unequaled for really heavy duty service, as *proved by years* of test under all mining conditions.

Goodman Electric Breast Machine

Standard Type

Enclosed Electrical Parts—Chain Guards

Slight alterations from plain design of the Standard Type machine permit enclosure of electrical parts for use in gaseous mines.

Easily removed hand-hole covers afford free access to commutator and brush holders.

The machine with electrical parts enclosed is in every other respect the Standard machine.

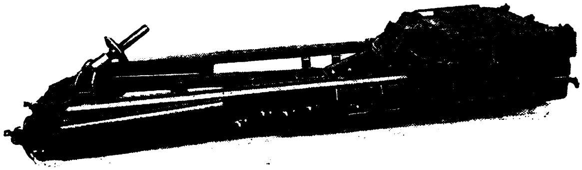
May have chain guards, as here shown, or be without them, as required.

Back jack is self-supporting—does not fall to the floor when released.

Rollers carry the heavy end, making shifting easy, *on skid or* bottom.

Goodman Electric Breast Machine

Low Vein Type



With Chain Guards

Has the Compound Wound Motor, so important in mining machine design.

Motor armature lies lengthwise, allowing room for generous bearings and gears.

Built very low, permitting operation in very thin coal.

Gearing is all readily accessible, making maintenance easy.

Sliding Frame is very stiff, insuring straight and free cutting.

Stationary Frame is of the same rugged construction as for the Standard machine, giving the necessary rigidity without excessive weight.

Chain Guards may be supplied as shown, or *omitted.*

May be made with electrical parts enclosed.

Goodman Electric Breast Machine

Standard Type

For Alternating Current

Has simple and powerful induction motor, the rotor of which cannot be burned out.

The power truck on which it moves is equipped with a planetary drive, which enables the stopping of the truck while the motor is still running, and gradually starting again without any shock or strain to any of the propelling parts.

Equipped with a three-conductor cable for three-phase circuits.

The machine, excepting the motor parts, is the same as the direct current machine shown on preceding pages.

May be fitted with chain guards when so desired.

Highly economical for the small mine which purchases power, available only in alternating curr

Goodman Air Breast Machine

Standard Type

Compressed Air Engine

The Goodman air driven breast machine runs as quietly and as free from vibration as an electric machine.

This is accomplished by the perfect balance of the engine.

Because of its smooth running and absence of vibration, the jacks are as easily held as on an electric machine.

Because of its smooth running and absence of vibration, the engine does not shake itself to pieces as do air driven breast machines of the old type.

Because of its smooth running and absence of vibration, the maintenance of this engine is easier and cheaper than for any engine of the old type.

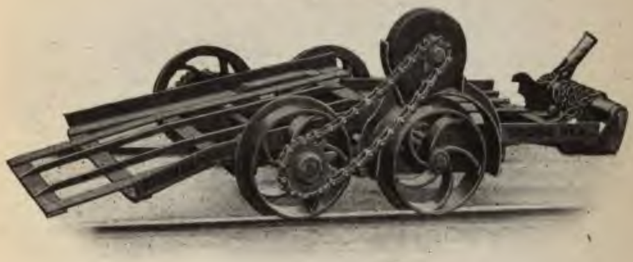
Because of its modern design, this air driven breast machine will cut coal with smaller consumption of air than any other similar machine.

The engine is so constructed that it will give *greater torque* for a given initial pressure than will *any other similar* machine.

And therefore this machine will run on low air *ressures,* where others will stall.

Goodman Drop-Front Trucks

For Mining Machines



Self-Propelling Drop-Front Truck

Loading Breast Machine on Drop-Front Truck

Has a parted platform, the front half hinged on the forward axle.

In unloading, this drop front forms an incline down which the machine slides freely to the floor.

In loading, the incline makes the work easy and rapid.

All four truck wheels remain always on the rails.

There is no derailing, nor erratic plunging of the truck as the machine slides off.

A very great improvement over the rigid tilting truck, and to be had only with Goodman Machines

Goodman Electric Shortwall Machine

A Continuous Cutter

Chain Guard Extended

A Continuous Cutting Machine for room and pillar work, and for work on long faces.

All movements and operations are made by the machine itself, under its own power.

This is of particular importance in low coal, where bars are not easily handled.

A front jack and stationary frame may hold and guide the machine in making its sumping cut into the coal, but usually the sumping is done without use of the front jack.

The stationary frame forms a perfect chain guard for the cutter arm at all times when not actually under the coal.

A pan shoe beneath the front jack supports the cutter arm off the floor while moving about the room.

As the cutter arm enters the coal the stationary frame (chain guard) telescopes back into the base of the machine.

The sumping cut is made at the right-hand side of the room, the feed and tail ropes led to anchors or jacks suitably set.

The sumping finished, the feed rope is led across

Goodman Electric Shortwall Machine

For Room and Pillar Work

In Cutting Position

the room to the left-hand wall, where the jack is again set.

The running cut across the face is then made, under perfect control, in one continuous operation.

A tilting device permits elevation or depression of the cutting, as conditions may require.

The machine is dragged back to its truck, loaded, moved to a new room, and there unloaded and set—all by its own power.

The machine is self-contained, without subsidiary parts for sumping or for supporting the cutter arm in moving.

The cutter arm is narrow; hence easily guided and not easily cramped under the coal.

Has compound wound motor, large parts, ample gearing, and is equipped for heavy duty service.

Working **ed, but** with large hand-
holes ded.

ctrical parts

Goodman Electric Shortwall Machine

On Self-Propelling Truck

Drop-Front Truck with Cable Reel Trailer

The two-unit system is the simplest and most satisfactory method for moving the cutting machine from place to place.

The main truck supports the cutting machine, while the trailer takes care of the cable automatically.

The independent trailer reel truck relieves the main truck of the additional parts required to pay out and wind up the cable. These parts are grouped in a self-contained unit.

With this two-unit system, sharper curves can be taken than with any other arrangement.

The trailer truck also affords a convenient and safe platform on which the runner may ride as the machine moves about.

Goodman Electric Shortwall Machine

Standard Type

For Alternating Current

Has a simple and powerful induction motor, giving maximum starting torque, with minimum starting current.

The rotor contains no joints of any kind over which current passes, and it cannot be burned out.

The power truck on which it moves is equipped with a planetary drive, which enables the stopping of the truck while the motor is still running, and gradually starting again without any shock or strain to any of the propelling parts.

Equipped with a three-conductor cable for three-phase circuits.

The machine, excepting the motor parts, is the same as the direct current shortwall machine shown on preceding pages.

Goodman Electric Longwall Machine

Plain or Reversible

Plain Longwall Machine

The most generally used longwall machine in this country.

Has all the desirable features for easy and positive control of the cutting.

The narrow cutter arm is easily tilted to permit cutting over or under obstructions, or to follow an uneven bottom.

Feed is powerful and positive, yet adjustable to suit varying conditions.

Motor is compound wound; armature lies lengthwise; gearing is large; all parts are heavy—the whole machine built for the severe and continuous duties always required in longwall work.

Goodman Electric Longwall Machine

Heavy Reversible Type

Arm in Position for Sumping In

Arm in Position for Running Cut

For use where conditions are unusually severe, requiring an extra heavy construction.

Built with either a direct-current compound-wound motor, or with an alternating-current induction motor.

After cutting in one direction, the cutter-arm can be swung around to the other side, permitting making a cut in the opposite direction.

Goodman Overcutting Machines

Straightface Type

Set for High Center Cutting

Set for Low Cutting

This machine cuts a **straight face,** thus providing the best shooting conditions, obviating tight corners and giving the maximum coal output for a given depth of cut.

Also cuts a **straight rib,** thus keeping the rooms and entries in the best condition.

Particularly adaptable for cutting in or near a band of dirt whose removal is to be facilitated.

May be converted from a center cutter to a top cutter, or vice versa, by inverting the cutting element.

All motor parts and gearing are enclosed.

Has attachment for boring anchor hole by power.

Is equipped with a chain guard.

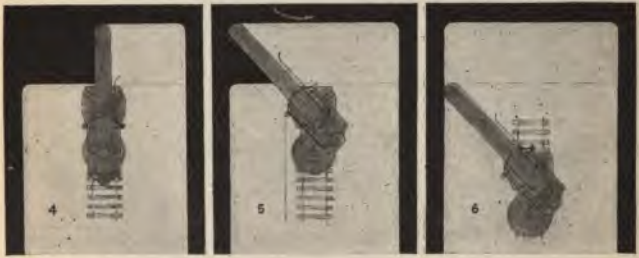
Goodman Overcutting Machines

Straightface Operation

1. The Machine arrives at the face in the room which is to be cut.

2. Ready to sump. Anchor set at the face and wire feed rope attached to it.

3. Sumping completed. Ready to start the straightface cut across the place.



4. Half way across on the straightface cut.

5. Straightface cut finished at the left side. Wire rope led back to a jack set behind the machine.

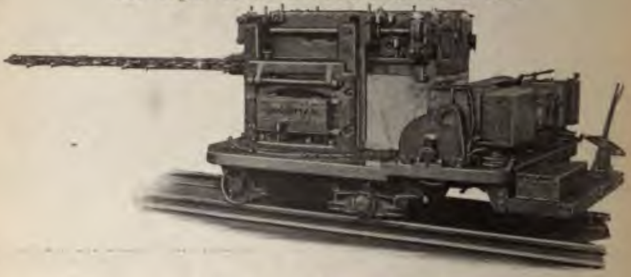
6. Square place cut completed by backing the machine along the track with the wire rope.

Returning the cutter-arm to position 1, the machine is ready to travel to its next working plac

Goodman Overcutting Machines

Slabbing Type

For High Center Cutting—Operating Side



Left Side of the Machine

For long face cutting, in either development or recovery work.

Improves the effectiveness of machine cutting by increasing the proportion of time during which actual cutting is done.

Swings its cutter arm to right or left at right angles to the track, for cutting faces of any lengths at either side.

Sumps into the coal by a simple swing from any position.

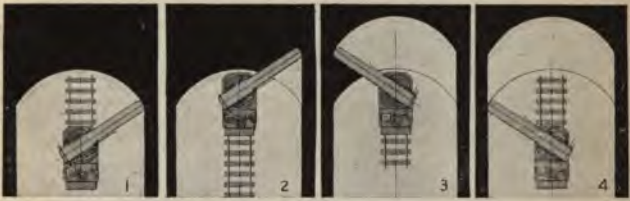
Useful in long-face advancement, in entry widening for track sidings, and in pillar drawing.

Self-propelling for rapid traveling.

Cuts from low to high center of seam, and becomes a top cutter by inversion of the cutting element in the side frames.

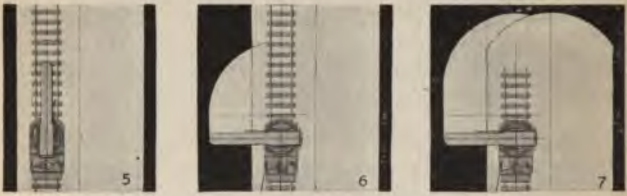
Goodman Overcutting Machines

Slabbing Operation



Driving Room or Entry

1. The machine at the face, ready to start cutting.
2. Sumped by straight advance on the track.
3. Circular face cut made by swing of the cutter arm.
4. Cut completed by backward movement of the machine along the track.



Slabbing A Long Face

5. Track laid at side of a room or along any face to be slabbed.
6. Slabbing cut as for entry widening—started by swinging sump of the cutter arm; continued by travel of the machine on the track.
7. Room development by slabbing off the pillar *backward* from the original room face. Simila *method* in pillar drawing.

Goodman Scraper Loader

For Loading Cars on the Entry

The Elements of the Complete Equipment

The Scraper Loader avoids necessity for laying track, taking top or placing cars in rooms.

It is particularly valuable in low coal or where bad pitches are encountered.

Useful also for face loading in room-and-pillar mines where long faces are worked. Also in longwall mines.

A complete outfit serves a panel of four or five rooms, from the time they reach a depth too great for shovel loading direct to cars on the entry, until they are fully driven up and the pillars drawn back.

The winding engine and the prop sheaves in the entry remain in fixed position until the work on this panel is completed, whereas the scraper is moved from room to room as the places are made ready to load out.

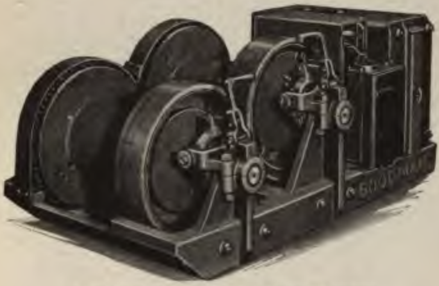
The outfit is operated by four or five men, the number depending on conditions. One man is stationed at the winding engine and one at the chute, who also trims the cars; the others are at the face.

Control is by bell signals.

The winding engine has tandem drums, with in-

Goodman Scraper Loader

Particularly Valuable in Low Coal



Tandem Drum Winding Engine

dependent clutches, permitting reversal of rope haul without reversal of motor.

Lead and tail ropes from the two drums pass between two pairs of center sheaves, giving fair lead to other sheaves from which the ropes enter the room to be loaded out.

Snatch blocks at the face—one at the left for the tail rope and two at the right for guiding the scraper in the loading—are held by jacks and are moved from room to room with the scraper.

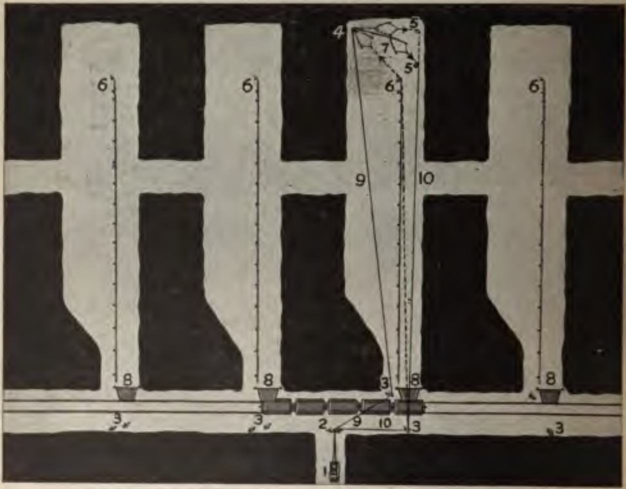
Planks attached at lower ends of a fairly straight line of props serve to guide the scraper in its travel. A steel channel with rollers forms the face end of this guide-way and is moved up as the room advances.

A steel chute at the entry delivers the coal from scraper to car, and is swung out of the way when the scraper is in use elsewhere.

In mines where bottom is taken on the entry the *scraper works* along the room bottom to the loading *chute*. Where bottom is not taken on the entry, a

Goodman Scraper Loader

Keeps Cars out of Rooms



Serving A Panel of Four Rooms

inclined trough of planks is built to enable the scraper to elevate the coal to loading height.

When a place is cleaned up, the tail rope is disconnected and, with both winding drum clutches engaged, the tail rope and the lead rope are wound in, pulling the scraper directly onto a mine car for transfer to the next ready place. The face snatch blocks being here reset, and the tail rope led around its block and back to the scraper, the operation of the loader may proceed.

Lead rope snatch blocks at the face are of open type, so the rope is easily thrown out when the scraper is loaded and in position for hauling out. These snatch blocks are set by jacks and can readily be moved about as the work requires. One setting for each is usually sufficient.

Goodman Scraper Loader

Two Methods of Operation

Where Bottom is Taken on the Entry

Where Bottom is Not Taken on the Entry (Top Taken Where Necessary)

1. Tandem drum electric winding engine.

2. Two pairs of center sheaves in a complete unit, attached by U-bolts to two wood props.

3. Room lead sheaves on brackets attached by U-bolts to props.

4. Tail rope face sheave (closed snatch block).

5. Two lead rope face sheaves (open snatch blocks).

6. Guide channel with rollers.

7. Scraper of plate steel, with chain for haul rope attachment.

8. Chute of steel, hung to swing out of the way when not in use.

9. Tail rope.

10. Lead rope.

Goodman Storage Battery Locomotive

Articulated Type

3000 Pounds Drawbar Pull

Battery operation, while affording numerous advantages over trolley operation, also imposes several conditions which must be recognized in a successful storage battery locomotive.

Goodman Storage Battery Locomotives are completely and particularly designed for operation with storage batteries.

In no detail do they follow blindly any feature of trolley locomotive practice which is not also in strict conformity to the best application of storage battery power.

First and most important, they remove from the *drivers the* excess of weight (due to the heavy bat-

Goodman Storage Battery Locomotive

Articulated Type

2000 Pounds Drawbar Pull

tery) over and above what is needed to give proper adhesion for tractive effort.

The Articulated type locomotive incorporates many advantageous features and is of highest standing for battery operation in mines.

It is designed by engineers of long experience in mine locomotive practice and has proved its fitness through several years of varied service.

It carries the battery between two bogy trucks, each of which has one pair of idle wheels and one pair of drivers.

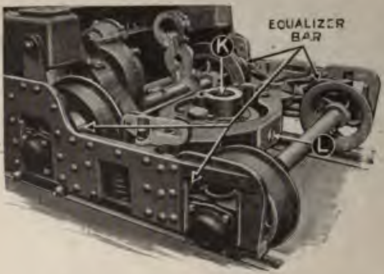
The battery sets low, being placed no higher than is necessary for clearance of small idle wheels beneath it, thereby permitting operation under low roof and keeping the center of gravity low, for desirable stability.

The articulated construction permits, as does no other type, the use of batteries of ample capacity.

The battery gets no heat from the working parts, none of them being beneath it or close to it.

Goodman Storage Battery Locomotive

Articulated Type



Equalizer Bars in the Truck

The Articulated locomotive will work around any mine track curve, by reason of the freedom afforded by the bogy trucks, each having short wheel base.

It will operate on the light rails usual in rooms and side entries, the weight being distributed over eight wheels instead of four.

It does not require excessive clearance for its cab corners at curves, the overhang of the bogy truck cabs being short.

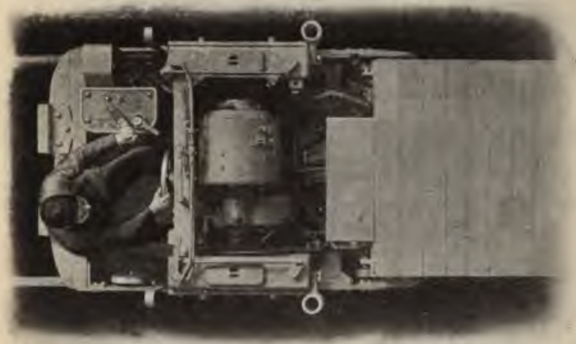
It does not throw its draw pin far off track center on curves, hence does not tend to derail cars at the turns.

The Articulated locomotive will not destroy mine track at curves, because the forward bogy truck acts as a pilot in taking the curves easily, at highest desirable operative speed.

Ball bearings at the king pins add to the facility of operation at curves.

Goodman Storage Battery Locomotive

Articulated Type



Ample Cabs—Accessible Parts

A large cab at each end affords comfortable and safe accommodation for motorman and trip rider.

All parts are easily accessible, no running parts but the idle axles being beneath the battery box.

Only so much weight being on the drivers as is necessary for development of desired drawbar pull, the battery and electrical parts have wheel-slippage protection against overload injury.

Electrical parts may be enclosed for service in gaseous mines.

Equalizer bars in the trucks assure equality of wheel pressures on uneven track.

Longitudinal stiffness is provided, to prevent tilting of the trucks under the action of drawbar pull.

Transversely the trucks have ample freedom for following uneven track, rounding banked curves, etc.

Goodman Storage Battery Locomotive

Articulated Type

Goodman Storage Battery Locomotives may be fitted for combination service, operating by trolley when traveling where overhead wiring is hung.

The motors have split field windings, giving two high-efficiency speeds of operation without the rheostat, and reduced resistance losses at other speeds.

Combination locomotives have two speeds on the battery and two higher speeds on the trolley, independent of the rheostat.

Goodman Storage Battery Locomotives are driven through gearing only, and all gears have teeth hardened by heat treatment.

Gears are encased and run in oil.

Single Truck Type

1000 Pounds Drawbar Pull

For light service a single-truck design is provided, as shown above, affording the same wheel-slippage protection of electrical parts, and all other important features of the Articulated type except those due to the bogy trucks.

Goodman Gathering Locomotive

For Large Cars, in Low Coal

With Electric Cable Reel

A highly successful gatherer for most exacting service in the more difficult of mining conditions.

Stands 30 inches above the rails to the top of its deck.

Trolley pole can be so attached that it may be depressed completely below the deck of the locomotive in operating under low roof.

Has flexible and short wheel base, to follow the mine track over uneven places and around sharp curves.

May be provided with electric cable reel for gathering use, driven either from the locomotive axle or by an independent motor.

Frame is of "unbreakable" composite construction—cast and rolled steel.

Spring bumpers and spring draft gear.

Controlling and breaking devices arranged to *facilitate* quick handling and rapid working.

Goodman Gathering Locomotive

For Small Cars and Low Roof

The "Electric Mule"

Designed as a small, compact gathering locomotive for effective work in light service.

Has short wheel base and small wheels, and will run wherever a mine car will go.

Has a single motor, geared flexibly to both axles.

Flexible axle support permits rapid operation over the rough and uneven track always found in rooms.

"Unbreakable" composite frame—steel plate sides and annealed cast steel ends.

Even with its short wheel base, the locomotive is positively non-teetering.

A very compact construction—100 inches long and 33 inches high. Three tons weight.

By variation of design a locomotive only 28 inches high may be supplied, in 2-ton or 2½-ton weight.

Fitted with one or two trolley poles and with gathering reel as required.

Goodman "Universal" Gathering Locomotive

Low Construction

Crab Reel Driven by Independent Motor

A gathering locomotive sometimes cannot go to the face, as in dip rooms, etc.

Provision of a wire rope and power-actuated winding drum enables the locomotive to remain on the entry and still reach the car at the face.

This feature, added to the usual electric cable reel, makes the locomotive truly a Universal Gatherer.

It may run the length of its electric cable away from the trolley wire and then reach the length of the wire rope to get a car.

The locomotive wheels may be locked by brakes to prevent movement while the rope is in use.

The wheels being outside, re-railing is very easy in case track conditions cause derailment.

Goodman "Universal" Gathering Locomotive

High Coal Type

Crab Reel Driven from Locomotive Motor

"Universal" equipment includes both electric and wire rope reels, but these locomotives may be without the electric reels when required for crab service only.

The wire rope drum, or crab reel, may be driven mechanically by clutch connection to the locomotive power, as above, or be operated by an independent electric motor, as on preceding page.

It may be operated with the locomotive standing or running.

Various types of Goodman locomotives are fitted *with this* feature, which is of value in many ways *esides room* gathering.

Goodman Electric Gathering Reel

Mechanically or Motor Driven

The Goodman Gathering Reel is a perfected device for performance of a very difficult service.

It may be driven mechanically from the locomotive itself or independently by a small motor provided for the purpose.

Conductor cable may be single or duplex, as conditions require.

Reels accommodate 300 to 500 feet of cable, single or duplex.

Cable is wound on in even layers by a simple *spooling* device.

Goodman Three-Motor Locomotive

For Heavy Haulage

20-Ton, with Motors Tandem Hung

Three-motor construction is particularly advantageous for heavy haulage of long trips over long distances.

The weight is distributed over six wheels, so a given track will safely carry a three-motor locomotive 50 per cent heavier than could be used in two-motor type. Or, for a given weight of locomotive the track may be one-third lighter than is required for a two-motor locomotive.

See table of comparative rail weights required for two-motor and three-motor locomotives, page 41.

Goodman Three-Motor Locomotive

Equalized Wheel Pressure

Side Frames of Box Construction

General details of design and construction are in conformity to the standards for two-motor types, as described at length on following pages.

Heavy side frames are of box form, each frame enclosing the equalizer system by which the locomotive weight, hung at four points, is distributed evenly to the six wheels, per diagram below.

Equality of wheel pressures assures utmost effectiveness in development of drawbar pull.

Equalizer System in the Side Frames

Goodman Two-Motor Locomotive

Outside Steel Frame

20-Ton, with Motors Centrally Hung

Goodman Two-Motor Locomotives have numerous features of superiority over others of similar type, both mechanically and electrically.

Frames are made with steel side plates, with cast steel ends of box type, by which construction the greatest possible frame rigidity is obtained.

The ends are built with spring bumpers and spring draft rigging.

Motors of high power are used, with fittings to correspond, to assure that the electrical equipment shall be no less strong and durable than the mechanical construction.

Excess of strength in the electrical parts provides the desirable margin of endurance not only for

Goodman Two-Motor Locomotive

Outside Steel Frame

15-Ton, with Long Wheel Base

momentary overloads, but also for continuous working at highest capacity.

Motors, with their bearings and gears, are made always ample, large dimensions being secured by closeness of arrangement and care in design.

Motor shells are provided with special covers for permitting access to commutators and brush holders, from above.

Motors are so hung, and their shells so divided, that the armatures—or the entire motors if desired—may be removed from above.

The controller is constructed for series and parallel running, and is of rugged construction, well enclosed.

Wheels may have chilled treads or steel tires, the *latter giving* about 25 percent better adhesion.

Goodman Two-Motor Locomotive

Inside Steel Frame

13-Ton, with Long Wheel Base

The inside frame locomotive, being no wider than the wheels, will operate in narrow entries.

Brakes are accessible for adjustment or for renewal of shoes.

Goodman "unbreakable" composite frame construction is here particularly adaptable.

Side frames of rolled steel, with cab and bumper ends of annealed cast steel.

Steel ends withstand all usual shocks of mine service, and are readily replaced when broken by erious accident.

Goodman Two-Motor Locomotive

Outside Steel Frame

10-Ton, with Long Wheel Base

Built in a wide range of weights, and with various equipment.

Any of the two-motor types may have spring bumpers, the springs acting both in pushing and in pulling.

Motors may be hung in tandem, one between the axles and one outside, or be hung inside, both between the axles.

Tandem hung motors give the short wheel base necessary for sharp curves.

Inside hung motors give the longer wheel base

Goodman Two-Motor Locomotive

Outside Steel Frame

8-Ton, with Short Wheel Base

permissible on curves of fair radius, and desirable for long runs.

A single reduction gear drive is used at each axle, the motor pinion meshing directly with the axle gear.

Brakes are very powerful, positive and quick, giving close control.

Trolley pole may be set low, and no part need project above the deck level.

Removal of covers forming the top of the locomotive *exposes* all parts.

Goodman Two-Motor Gatherer

For Low Coal Work

6-Ton, Inside Steel Frame

Sand boxes are placed high in the frame, giving good head for delivery of sand to the rails close to the wheels.

The locomotive shown on this page is especially adapted for mine development, wherein the locomotive does main haulage work as well as gathering.

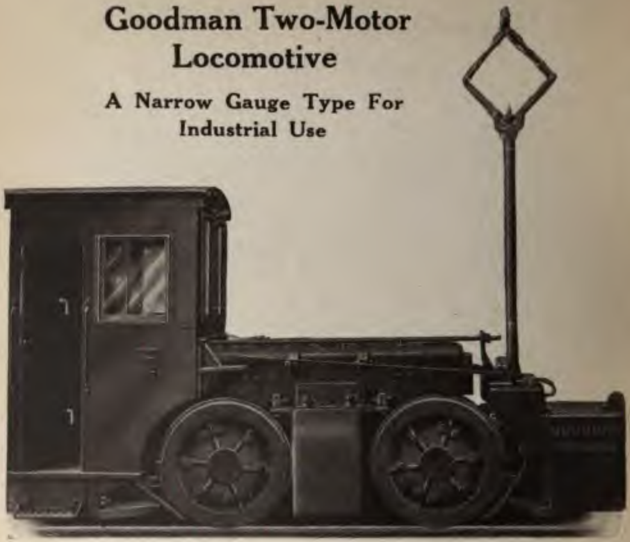
Has quick-acting brakes, as needed in switching and gathering.

May be fitted with power-driven drum for wire rope reel, when its work will include gathering from dip rooms.

Provision of two trolley pole sockets is often a feature of convenience and value.

Goodman Two-Motor Locomotive

A Narrow Gauge Type For Industrial Use



With Covered Cab for Outdoor Work

A two-motor locomotive of high power, for very narrow gauges. Built in weights of 10 to 15 tons.

Similar to the Goodman Single-Motor type in several important features of design.

Has the unit drive for all four wheels—giving a maximum of hauling capacity.

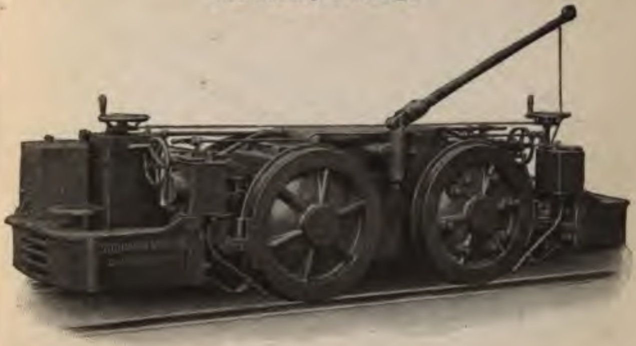
Has the flexible axle support, so necessary for operation on uneven tracks.

A thoroughly satisfactory narrow gauge locomotive for industrial service.

The same locomotive, without cab, is built for mine use on narrow gauge tracks.

Goodman Single-Motor Locomotive

For Heavy Haulage



10-Ton, Double-End Control

The maximum possible pulling power per ton of weight in a traction locomotive.

A patented design, made exclusively by the Goodman Manufacturing Co.

Has a single armature, geared to both axles.

Hence all four wheels are constrained to act always in unison—a unit of tractive effort.

In this feature of unit drive lie many items of time saving in haulage work.

No wheel can slip until they all slip, and all four wheels revolve always at the same speed.

A heavier load may therefore be started, without slippage, than when the two axles are free to act independently.

The motorman may start his trip and get up to *running* speed in shortest possible time, because the

Goodman Single-Motor Locomotive

A Unit of Pulling Power

7½-Ton, Single-End Control

rapidity with which he can turn on current is determined by the adhesion of four wheels instead of only two.

Perfect flexibility of operation is secured by application of the three-point principle of support in the construction and mounting of the frame.

The weight of the locomotive being equally divided between the two axles, one-fourth of the total weight is borne always by each wheel.

And that means equality of pressures, regardless of irregularities of track surface.

And this in turn insures constancy of adhesion for pulling, regardless of track irregularities.

Constant equality of wheel pressures also minimizes the severity of the service on the track itself.

The flexible truck reduces liability to derailment,

Goodman Single-Motor Locomotive

For Entry Gathering

6-Ton, with Gathering Reel

enabling the wheels to follow more surely a poorly laid track.

Also a higher speed may safely be maintained over bad spots in the track.

All working parts are made readily accessible, **from above,** by lifting off the top magnet.

No pit is required in the shop, as there is no underneath work to be done.

No heavy parts overhang the axles, so the weight is concentrated mainly within the wheel base.

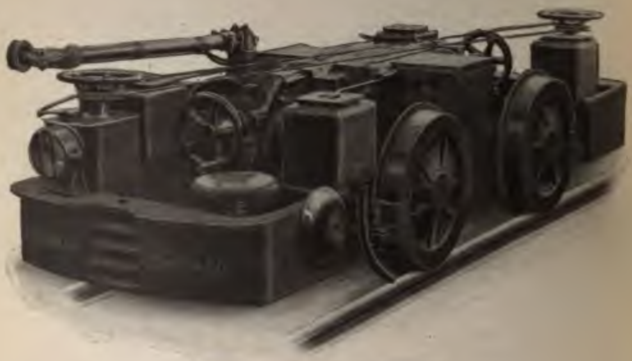
Wheels and brakes are outside, facilitating adjustment and renewal of brake shoes.

Wheels may have chilled treads or be fitted with steel tires.

The one motor, lengthwise of the locomotive, has *ample room* for generous proportions in all parts.

Goodman Single-Motor Locomotive

For Light Haulage



5-Ton, Double-End Control

Wholly within the wheels, this locomotive may be operated in the narrowest of entries.

It lends itself readily to arrangement for double-end control, so desirable in many situations.

Central frame is a single casting of great strength and rigidity.

Cabs are annealed cast steel, bolted on and hence readily renewable, though not easily broken.

Driving gears are bolted directly to the wheels, relieving the axles of needless bending stresses.

Brakes are direct, positive and quick, enabling *close control* at all times.

Sand boxes are placed high, giving good head *for flow* of sand to the rails.

Goodman Metal Mining Locomotive

Single-Motor Type

A "Safety-First" Locomotive, with Guarded Wheels

The Goodman Single-Motor Type has proved itself particularly adapted to haulage work in metal mines.

Its design permits perfectly practical construction of a locomotive of large horsepower for narrow gauge tracks.

The standard design, with a few special features, meets all the peculiar requirements of this work.

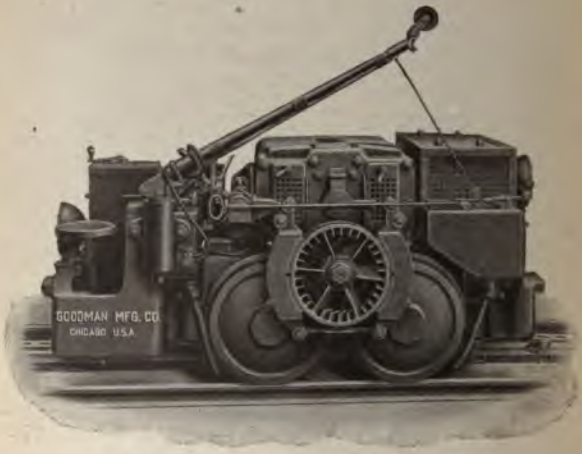
The flexibility of axle support in the single-motor design is of usual value in metal mining work.

Unit driving for all four wheels affords here also the maximum of hauling power for a given weight.

Double-end control is of special value, as the locomotive in many mines is reversed at the shaft "station."

Goodman Rack Rail Haulage

For Hilly Mines



100 Hp. Combination Rack Locomotive

The Goodman Rack Rail Haulage is the only practical Rack Locomotive system ever built for mine service.

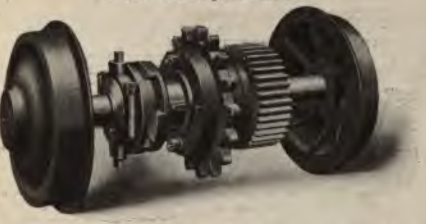
Plain Rack System for operation by rack rail only—advisable where grades prevail.

Combination System for mines where the roadways are generally level, or nearly so, and where grades are only local or not predominant, permitting operation by traction on the level stretches and by rack on the grades, where the rack rail is laid.

A single motor of ample proportions, geared to *both driving* axles for traction running, or to both *driving* sprockets (see next page) for rack operation.

Goodman Rack Rail Haulage

For Heavy Grades



Driving Arrangement for Combination Traction and Rack Operation

By shifting a clutch the motor power may be transmitted to the axle and track wheels for traction operation.

Standard Rack Rail Track

The rack rail is made up of flat steel bars, perforated accurately to receive the teeth of the driving sprockets, and joined end to end by bolted fish plates.

The rack rail is supported rigidly above a stringer on the ties by carefully formed clamp chairs.

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